

Step by Step®

Oral Radiology



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Step by Step[®] Oral Radiology

Ram Kumar Srivastava

BSc BDS MDS LLB

Professor and Head
Chandra Dental College and Hospital
Barabanki, UP, India

Ex-Acting Principal
Vinayaka Mission Dental College
Sitapur, UP, India

Ex-Principal
Career Dental College, Lucknow, UP, India
Suyash Dental College, Gorakhpur, UP, India

Foreword

VB Sahai



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Corporate Office

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Registered Office

B-3 EMCA House, 23/23B Ansari Road, Daryaganj, **New Delhi** - 110 002, India

Phones: +91-11-23272143, +91-11-23272703, +91-11-23282021

+91-11-23245672, Rel: +91-11-32558559, Fax: +91-11-23276490, +91-11-23245683

e-mail: jaypee@jaypeebrothers.com, Website: www.jaypeebrothers.com

Offices in India

- **Ahmedabad**, Phone: Rel: +91-79-32988717, e-mail: ahmedabad@jaypeebrothers.com
- **Bengaluru**, Phone: Rel: +91-80-32714073, e-mail: bangalore@jaypeebrothers.com
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- **Kochi**, Phone: +91-484-2395740, e-mail: kochi@jaypeebrothers.com
- **Kolkata**, Phone: +91-33-22276415, e-mail: kolkata@jaypeebrothers.com
- **Lucknow**, Phone: +91-522-3040554, e-mail: lucknow@jaypeebrothers.com
- **Mumbai**, Phone: Rel: +91-22-32926896, e-mail: mumbai@jaypeebrothers.com
- **Nagpur**, Phone: Rel: +91-712-3245220, e-mail: nagpur@jaypeebrothers.com

Overseas Offices

- **North America Office, USA**, Ph: 001-636-6279734,
e-mail: jaypee@jaypeebrothers.com, anjulav@jaypeebrothers.com
- **Central America Office, Panama City, Panama**, Ph: 001-507-317-0160,
e-mail: cservice@jphmedical.com Website: www.jphmedical.com
- **Europe Office, UK**, Ph: +44 (0) 2031708910, e-mail: info@jpmepub.com

Step by Step® Oral Radiology

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To

*My parents
Krishna and Prithwi Nath
whose encouragement and sacrifice
helped to take it all possible.*

FOREWORD

In dentistry, as in medicine, a thorough pre-treatment examination is usually incomplete unless the clinical findings are supplemented by visual information obtained from images produced through the use of ionizing radiation.



In today's modern dental practice, examination of the teeth and their supporting osseous structures without the use of radiographs is unimaginable. Indeed, two-dimensional radiographic images of teeth and bones of the jaws have become the lynchpin on which the diagnosis of all oro-dental diseases hinges. In addition to radiography, MRI, scintigraphy and sonography have also become indispensable tools in the hands of a discerning dental diagnostician.

Although dental radiography has been in vogue for over a century, the importance of both patient and operator protection is often overlooked in the dental environment. Modern advances, e.g. digital radiography and radiovisiography has made a significant contribution in reducing exposure, saving time and improving quality of the images.

This timely text on "Oral Radiology" authored by Dr Ram Kumar Srivastava is a step forward in fulfilling the lacuna being felt by dental students for an "easy-to-understand" book on this subject. It will

also find its niche in the education and training of dental hygienists, radiology technicians and dental assistants. I am sure that practicing dentists of all specialties will also find this book useful as it provides important advice and clinical tips on radiographic techniques and diagnosis.

I congratulate the author on his endeavor and wish him success.

VB Sahai

Vice-Chancellor
Subharti University
Meerut, UP, India



PREFACE

The aims and objectives of the book *Step by Step Oral Radiology* is to provide a basic and practical knowledge in the subject of dental radiography required by undergraduate and postgraduate dental students. I have simplified and condensed very large and complex subject. The book is containing the text along with the diagrams and photographs for better understanding of the topics.

I have covered all the diseases related with the teeth and jaws and their normal appearance in radiographs.

Imaging in dentistry is now recently introduced as a new technology into everyday clinical practice. Digital imaging including cone beam CT, MRI, ultra sonography, scintigraphy is included in the book.

This book is according to the syllabus of Dental Council of India. The contents of the book satisfy the requirement of most undergraduate and postgraduate dental students from examination point of view.

I hope this book gives a clear, logical and easily understandable text that make a positive contribution to the teaching and learning of dental radiology.

Ram Kumar Srivastava



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This book has only been possible with enormous amount of help and encouragement from my family and colleagues.

Firstly, I would like to give grateful thanks to Dr Anil Kohli who has given advise in specific chapters. My special thanks also to Dr PN Awasthi, Secretary DCI and Dr VB Sahai, Vice-Chancellor, Subharti University, Meerut, for their help and comments. I am fortunate to work with such able and efficient personalities.

I am grateful to Dr Ashish Asthana, Dr Mohit Seth, Dr Vikram Ahuja and students of Career Dental College, Lucknow, Chandra Dental College, Barabanki and Dental faculty of CCMV Lucknow for diagrams, photographs and help in the production process.

Special thanks to my wife Surabhi, son Syamantak, Swapnil and brothers Sudhir and Krishan without their help this project would never have been completed.



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Chapter 1

Introduction

The discovery of X-ray in 1895 by Wilhelm Conrad Roentgen started with the history of radiography. Roentgen used a vacuum tube, an electric current and special screens covered with a material that glowed (fluorescent) when exposed to radiation. He discovered a glow or fluorescence which was coming from screens when cathode rays (streams of electrons) passing from one end of the tube to the other. He realized that something from the tube was striking the screens and causing glow and named this unknown rays as X-rays.

Johana Wilhelm Hittorf, a German physicist, used the vacuum tube to study fluorescence. In 1870, William Crookers, an English chemist, designed the tube which was later known as the Hittorf-Crookes tube. In 1913, William D Coolidge, an electrical engineer, developed the first hot cathode X-ray tube, a high vacuum tube that contained a tungsten filament. Weston Price introduced the bisecting technique in 1904, and the paralleling technique was first introduced by C Edmund Kells in 1896.

X-ray forms part of the electromagnetic spectrum at the high energy end, the visible light in the middle and microwaves and radio waves at the low energy end. The X-rays are energetic enough to ionize atoms and break molecular bonds as they penetrate tissues and are therefore, called ionizing radiation. X-rays are produced when high-energy electrons strikes a high atomic number material. This interaction is produced within an X-ray tube. A high voltage is passed across two tungsten terminals. One terminal (cathode) is heated until it liberates free electrons. When a high voltage is applied across the terminals, the electrons accelerate toward the anode at high speed. On hitting the anode target, X-rays are produced.

X-ray picture is produced due to interaction of the ionizing radiation with tissues as it passes through the body. Tissues of different densities are displayed as distinct areas depending on the amount of radiation absorbed. The four different densities are: gas (air), fat, soft tissue and fluid and calcified structure (bone). Air absorbs the least amount of X-ray and, therefore, appears black (radiolucent) on radiograph, whereas calcified structures (bone) absorb the most, resulting in white radiopacities, soft tissue and fluid appear grey on a radiograph.

Chapter 2

Atomic Structure

The atom is a miniature solar system consisting largely of empty space. At the center of the system is the nucleus (approx. 10^{-15} m diameter) and around the center the electrons move in orbits (approx. 10^{-11} m diameter). The simplest atom (hydrogen), consists of one positively charged particle (a proton) and one electron in orbit.

Matter is composed of atoms that occupy space. The atom can further be broken down into elementary components consisting of the electron, proton and neutron. All known substances (living and nonliving) are from these elemental components. Combinations of these elemental particles determine the atomic structures. The atomic number, based on the number of protons, is used to classify each element.

The number of protons (positive charged) in the nucleus is called the atomic number, Z which is equals to the number of orbiting electrons in the neutral atom. Since a proton is around 1840 times heavier than an electron, practically all the mass of the atom lies in the nucleus. For each element, except hydrogen, the nucleus contains both protons and neutrons. Protons (positive charged) and neutrons (neutral charged) collectively form the nucleus of the atom (Fig. 2.1).

Atomic weights are usually different from the atomic masses because most naturally occurring elements have a number of stable isotopes. For example, chlorine consists of a mixture of two isotopes, chlorine-34 and chlorine-36 having atomic weight 35.46.

ELECTRON SHELLS

The electrons around the nucleus are located in a few specific orbits or shells, the nearest to the nucleus is labeled the K orbit and subsequent ones are given the labels L, M, N, etc. The K orbit is the one with the least energy but the greatest

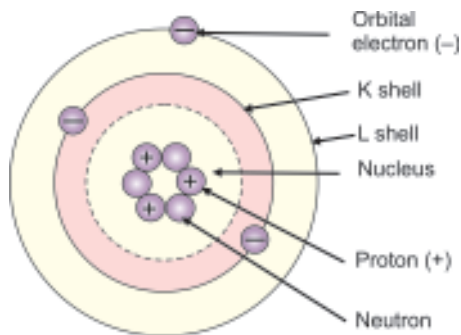


Fig. 2.1: An atom of lithium, whose atomic number is 3 and mass number is 6

binding energy. The K shell is the strongest and requires the most energy to displace an electron from its orbit. If an electron is moved from a higher energy shell to a lower one, energy is released. Each orbit can hold only a limited number of electrons, the maximum number in the n^{th} orbit is $2n^2$ (e.g. the M shell is the third and can only have up to 18 electrons). In general, the electrons occupy the innermost orbits, but the outermost shell will never have more than eight electrons before the next outer shell starts to fill.

IONIZATION AND EXCITATION

At the atomic level, the atom is said to be ionized when an electron is completely removed from the electrostatic field around the nucleus, and the process is known as ionization (Fig. 2.2). If the electron is only partially removed, i.e. moved from one orbit to a more distant orbit, the atom is said to be in an excited state and the process is known as excitation. The ionized or excited atom will resume its stable state by attracting an electron into the vacant space in the orbit

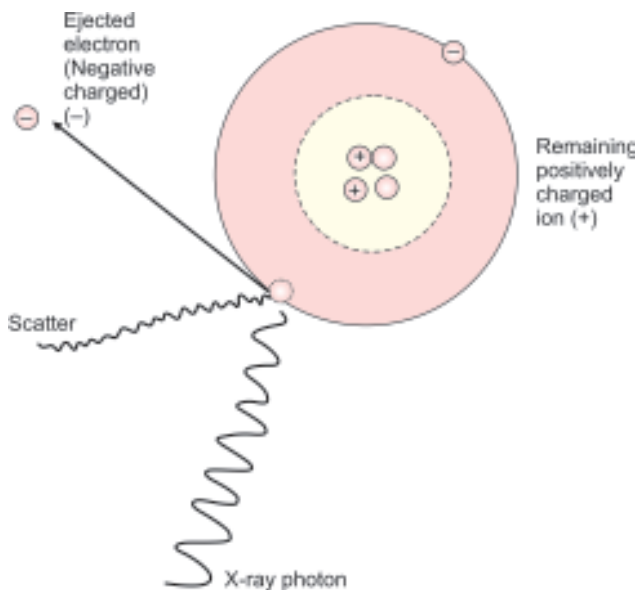


Fig. 2.2: Ionization process when X-ray photon interacts with a neutral atom to form negative charged electron and positive charged proton

concerned. This inward movement of the electron through the shell structure is accompanied by the emission of electromagnetic radiation, which may be visible as fluorescence in the discharge tube, or invisible X-radiation, depending on the difference in the binding energies of the two orbits. Excitation and ionization may be initiated by high-energy particles or by electromagnetic radiations.

Normally, an atom is in a non-ionized state with an equal number of protons and electrons. When this balanced state is disturbed, the displaced orbital electron and the atom from which it originated is called an ion pair. This situation can

occur with electron bombardment of matter, X-ray bombardment of matter, thermionic emission with electron release, chemically and many others. If the ionized electron is moved to a higher orbit, this is called excitation. In an excited state, the displaced electron returns to its original orbit or is replaced by another electron. Often the additional energy needed to ionize the atom is released as photons of electromagnetic, heat or chemical energy.

RADIATION AND RADIOACTIVITY

Radiation is the emission and propagation of energy through space or a substance in the form of waves or particles. The terms 'radioactivity and radiation' are sometimes make us confuse, so remember that they are not the same thing.

Radioactivity is defined as the process by which certain unstable atoms or elements undergo spontaneous disintegration, or decay, in an effort to attain a more balanced nuclear state. A substance is considered radioactive, if it gives off energy in the form of waves or particles as a result of the disintegration of atomic nucleus.

IONIZING RADIATION

Ionizing radiation is defined as radiation that is capable of producing ions by removing or adding an electron to an atom. Ionizing radiation can be classified into two types: particulate and electromagnetic.

X-radiation is a high-energy, ionizing electromagnetic radiation. Like all electromagnetic radiations, X-rays have properties of both waves and particles. X-rays can be defined as weightless bundles of energy (photons) without an electrical charge that travel in waves with a specific frequency at the speed of light. X-ray photons interact with the materials they penetrate and cause ionization.

PARTICULATE RADIATIONS

These are tiny particles of matter that possess mass and travel in straight line at high speeds, which transmit kinetic energy by means of their fast moving small masses.

Types of Particulate Radiation:

(a) *Electrons are of two types*–

- (i) Beta particles are fast moving electrons emitted from the nucleus of radioactive atoms.
- (ii) Cathode rays are streams of high speed electrons that originate in an X-ray tube.

(b) **Protons:** These are accelerated particles, such as hydrogen nuclei with a mass of 1 and a charge of +1.

(c) **Neutrons:** These are accelerated particles with a mass of 1 and no electrical charge.

(d) **Alpha particles:** These are emitted from the nuclei of heavy metals such as He^{2+} .

ELECTROMAGNETIC RADIATION

Electromagnetic radiation is the propagation of wave like energy (without mass) through space or matter. The energy in electromagnetic radiations is propagated by oscillating electric and magnetic fields positioned at right angles to one another. These radiations are man made or occur naturally, such as cosmic rays, infrared, high radio waves, radar waves and microwaves. Electromagnetic radiations are arranged according to their energies as in the electromagnetic spectrum. In electromagnetic radiation only high energy radiations (cosmic rays, gamma rays and X-ray) are capable of ionization.

Electromagnetic radiations are transmitted in space as both a particle or quantum and a wave. Hence two theories

are considered—particle (Quantum) theory and wave theory.

Particle (Quantum) Theory

The particle theory says that energy travels as packets of energy called photons or quanta that have neither mass nor charge that travel as waves at the speed of light.

Wave Theory

The wave theory says that energy travels as two waves, an electrical and a magnetic wave which travels together at right angles to each other, at a speed of 3×10^8 meter/second.

The energy in the waves depends on the following properties:

- (a) **Velocity:** It means the speed of the wave. All electromagnetic radiations travel as waves at the speed of light (3×10^8 meter/second).
- (b) **Wavelength:** It is the distance between the crest of one wave and the crest of the next wave. By the wavelength, the energy and penetrating power of the radiation can be determined, the shorter the wavelength (i.e. the distance between the crests), the higher the energy and ability to penetrate matter. The unit of measuring wavelength is nanometers (1×10^{-9} meter) for short waves and in meters for longer waves.
- (c) **Frequency (Hz):** It is the number of wavelengths that pass a given point in a certain amount of time. Frequency and wavelengths are inversely related, if the frequency is high, the wavelength will be short and if the frequency is low, the wavelength will be long. X-ray photons are common between 0.1 and 0.5 Å and 10^{18} to 10^{21} Hz.

Frequency of these rays increases

←
from radio waves to gamma rays

Gamma rays	X-ray	UV	Visible light	Infrared	TV rays	Radar	Micro-waves	Radio waves
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Wavelength of these rays increases

→
from gamma rays to radio waves

Electromagnetic Spectrum

Low frequency electromagnetic radiations have a long wavelengths and less energy while high frequency electromagnetic radiations have a short wavelength and more energy.

- (d) **Amplitude:** Amplitude is the height of the wave from this point to midpoint or through to midpoint.

Electromagnetic energy is arranged in an orderly fashion according to the wavelength. For medical X-rays this range is from approximately $0.1 \text{ \AA}$ to $0.5 \text{ \AA}$ (0.01 to 0.05 mm). This energy travels in the form of sine wave-like oscillations at the speed of light.

TYPES OF X-RAY RADIATION

- (a) **Primary radiation:** Primary radiations are that radiations which produce at the target of the anode and are the penetrating X-ray beam. This X-ray beam is known as the primary beam or useful beam.
- (b) **Secondary radiation:** It is that radiation which is created when the primary beam interacts with the matter such as bone, soft tissue and teeth. This radiation is less penetrating than primary radiation.
- (c) **Scatter radiation:** This radiation is the result of an X-ray that has been deflected from its path by the interaction

with the matter. Scatter radiation is detrimental to both the patient and the operator because this radiation is deflected in all directions by patient tissues.

Coherent Radiation

This is a type of scattered radiation that may take place when X-rays interact with matter. Coherent radiation is produced when a low energy X-ray photon has altered its path by interaction with the matter and no loss of energy and no ionization occurs. Only an X-ray photon scattered radiation is produced.

CONTINUOUS RADIATION SPECTRUM

X-rays are produced whenever high-energy particles are suddenly slowed in a target. This process is unlikely at low particle energies but becomes increasingly more probable at higher energies. The energy lost by the particle appears directly as a photon of bremsstrahlung radiation (from the German word bremsen = brake and Strahlung = radiation). At the atomic level, this braking results from the interaction between the particle and the electrostatic field near the nucleus. For particles of a given energy, the deceleration varies directly with the square of the atomic number, Z , of the absorber and z , the number of unit-charges on the particle, and inversely with the mass of the particle, m . Thus the intensity of bremsstrahlung varies between charged particles and materials as Z^2/z^2m . It follows that particles of small mass, such as electrons and positrons, are much better producers of bremsstrahlung than heavier particles. Similarly, materials of high atomic number, such as lead and tungsten, are more efficient producers of bremsstrahlung than low atomic number material such as plastic and soft tissue.

In the X-ray tube, the fast electron may lose all its energy in a single interaction with the electric field around the target nucleus. It is more likely, however, that it will lose only a part of its energy in that first interaction and then proceed further, interacting with other target atoms before coming to rest. It follows that a beam of electrons interacting with the target will produce X-ray photons with energies spread over a range from very small values up to the maximum energy of the electrons in the beam. Different amounts of energy are lost by the particles at each bremsstrahlung event. The maximum energy of the bremsstrahlung will equal the maximum energy of the particle and corresponds to the particle losing all its energy in one interaction. The bremsstrahlung radiation appears as a continuous spectrum.

The continuous spectrum has a maximum photon energy (keV) equal to the tube voltage (kV). Photons of maximum photon energy have the minimum wavelength in the spectrum. Wavelength is inversely proportional to photon energy.

PRODUCTION OF X-RAYS

Electrons traveling from the filament to the target convert some of their kinetic energy into X-ray photons by the formation of bremsstrahlung and characteristic radiation (Fig. 2.3).

BREMSSTRAHLUNG RADIATION (GENERAL RADIATION)

Bremsstrahlung interactions, the primary source of X-ray photons from an X-ray tube, are produced by the sudden

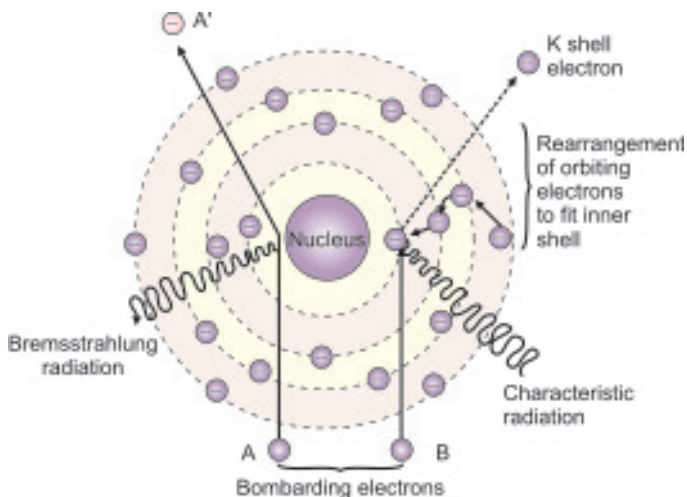


Fig. 2.3: Diagram showing bremsstrahlung radiation and characteristic radiation

stopping or slowing of high-speed electrons at the target. When electrons from the filament strike the tungsten target, X-ray photons are created if the electrons hit a target nucleus directly or if their path takes them close to a nucleus. If a high-speed electron directly hits the nucleus of a target atom, all its kinetic energy is transformed into a single X-ray photon. The energy of the resultant photon (in keV) is numerically equal to the energy of the electron. This in turn is equal to the kilovoltage applied across the X-ray tube at the instant of its passage.

Most high-speed electrons, however, have near or wide misses with atomic nuclei. In these interactions, a negatively charged high-speed electron is attracted toward the positively charged nuclei and loses some of its velocity. This deceleration

causes the electron to lose some kinetic energy, which is given off in the form of many new photons. The closer the high-speed electron approaches the nuclei, the greater is the electrostatic attraction on the electron, the braking effect and the energy of the resulting bremsstrahlung photons.

Bremsstrahlung interactions generate X-ray photons with a continuous spectrum of energy. The energy of an X-ray beam may be described by identifying the peak operating voltage (in kVp). A dental X-ray machine operating at a peak voltage of 70,000 volts (70 kVp), for examples, applies a fluctuating voltage of as much as 70 kVp across the tube. This tube therefore produces X-ray photons with energies ranging to a maximum of 70,000 eV (70 keV).

CHARACTERISTIC RADIATION

Characteristic radiation occurs when an electron from the filament displaces an electron from a shell of a tungsten target atom, thereby ionizing the atom. When this happens, a higher energy electron in an outer shell of the tungsten atom is quickly attracted to the void in the deficient inner shell.

When the outer-shell electron replaces the displaced electron, a photon is emitted with energy equivalent to the difference in the two orbital binding energies. Characteristic radiation from the shell occurs only above 70 kVp with a tungsten target and occurs as discrete increments compared with bremsstrahlung radiation. The energies of characteristic photons are a function of the energy levels of various electron orbital levels and hence are characteristic of the target atoms. Characteristic radiation is only a minor source of radiation from an X-ray tube.

ELECTRICAL ENERGY CONVERSION TO X-RADIATION

Alternating current (AC) is converted into direct current (DC) by an electrical transformer. This direct current is then put into motion (Kinetic energy) from cathode to anode in the X-ray tube to produce heat (thermal energy) and X-radiation (radiant energy).

The filament (cathode) of the X-ray tube is heated to incandescence causing electrons to "boil off" in a process known as thermionic emission. The electrons energy is converted into heat and X-ray energy.

The milliamperage setting determines the number of released electrons available for interaction. The range of the applied voltage (kilo volt) determines the wavelength and thus the energy of the X-ray photons. The relation of voltage and amperage to resistance can be expressed by Ohm's law, which states that:

$$I = \frac{V}{R}$$

Where I = amperage, V = voltage and R = resistance.

ELECTRON INTERACTION WITH THE ANODE OF THE X-RAY TUBE

More than 99% of the energy is converted into thermal energy (heat). The remaining energy is divided among bremsstrahlung and characteristic radiation.

Bremsstrahlung radiation is also known as general radiation, the continuous spectrum or white radiation. Production of bremsstrahlung radiation is from the "braking" action that occurs as the electrons interact with the anode. This process involves electrons that generally pass by the heavy nuclei of the metallic atoms in the target material. The attraction between the negatively charged electrons and the

positively charged nuclei causes the electrons to be deflected and decelerated from their original path and to lose some of their energies. Since energy cannot be destroyed, the energies lost by the electrons are transformed and emitted as X-ray photons.

The considerable rate of deceleration causes the emission of short wavelength radiation in the form of X-rays. As this braking action varies, so does the intensity of the resultant X-ray energy. In the 70 to 100 kVp ranges, using tungsten anode, these bremsstrahlung rays constitute about 90% of the radiation emitted as X-rays. For example, to produce characteristic radiation with a tungsten target, at least 70 kVs is required for K-shell interaction, because the K-shell electron of tungsten is held with 69.53 effective kilovoltage. Characteristic radiation produced in the interaction of X-rays with matter is usually referred to as secondary radiation and is a form of scatter.

X-RAY INTERACTION WITH MATTER

X-ray interact with all forms of matter. This interactions with matter result in absorption of energy and thus attenuation of the X-ray beam (reduction in intensity of the X-ray beam) and the production of secondary radiation. The X-ray energy absorbed by the tissue causes chemical changes that result into tissue damage by ionization and free radical formation (Fig. 2.4).

When X-rays are absorbed by matter, positive and negative ions and secondary radiation are formed from previously neutral atoms. The amount and type of absorption that takes place depend on the energy of the X-ray beam (the wavelength) and the composition of the absorbing matter. The thicker the material the more X-rays will be absorbed. The other factors which determine the

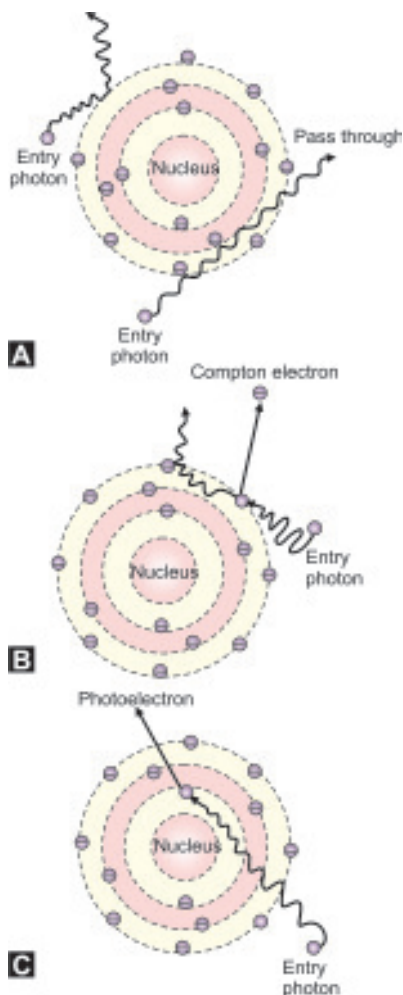


Fig. 2.4: X-ray interaction with matter A—Thompson effect, B—Compton effect, C—Photoelectric effect

X-ray absorption are the number of orbiting electrons, the numbers of protons and neutrons in the nucleus of the atom.

When X-rays are absorbed by any material that does not become radioactive because X-rays have no effect on the nucleus of the absorbing atom, affecting only the atom's orbiting electrons. Thus the equipments or walls in a dental X-ray room do not become radioactive after continuous exposure to radiation.

Four possibilities can occur when an X-ray photon interacts with tissue:

1. No interaction the X-ray photon can pass through the atom uncharged and leave the atom unchanged. This happens about 9%.
2. **Thompson scatter (coherent scatter):** In this effect the X-ray photon has its path altered by the atom. There is no change to the absorbing atom, but a photon of scattered radiation is produced. This accounts for about 8% of the interaction.
3. **Photoelectric effect:** The X-ray photon can collide with an orbiting electron giving up all energy to dislodge the electron from its orbit. The photoelectron that is produced has a negative charge and the remaining atom has a positive charge. This is ionization and this interaction takes place about 30% of the time with dental X-rays.

The X-ray photon collide with a loosely bound electron of an outer shell of the atom and only give up part of its energy in ejecting the electron from its orbit. This results in a negatively charged ejected Compton electron, a photon of scattered radiation and a remaining atom that is now positively charged. This effect is ionization and takes place about 62% of the time with dental X-rays.

4. **Compton effect:** In both the Compton and photoelectron interactions, the ejected high-speed electron interacts with other absorbing tissue and causes further ionization,

excitation breaking of molecular bonds, all of which causes adverse tissue effects.

X-RAY MACHINE

X-ray machine is the machine for generating X-rays. The component parts of an X-ray machine are X-ray tube head, control panel and the extension arm (Fig. 2.5).

X-ray Tube Head

It is a tightly sealed heavy metal housing that contains the X-ray tube that produces dental X-rays. The component parts of the tube head are:

- Metal housing or body of the tube head that surrounds the X-ray tube and transformers and is filled with oil and protects the X-ray tube.



Fig. 2.5: Dental X-ray machine

- **Insulating oil:** This oil is present surrounding the X-ray tube and transformers inside the tube head. It prevents overheating by absorbing the heat created by the production of X-rays.
- **Tube head seal:** It is made up of aluminum or leaded glass covering the tube head and permits the exit of X-rays from the tube head. It acts as a filter to the X-ray beam.

Aluminum disks or sheets: 0.5 mm thick aluminum disks are placed in the path of the X-ray beam. These disks filter out the non-penetrating longer wavelengths X-rays.

Collimator: A lead plate with a central hole that fits directly over the opening of the metal housing where the X-rays exit. It restricts the size of the X-ray beam.

Position-indicating device (PID): This is open ended cone-shaped lead lined cylinder that extends from the opening of the metal housing to the tube head. It aims and shapes the X-ray beam.

X-RAY TUBE

The X-ray tube is the heart of the X-ray generating systems. The X-ray tube is positioned within the tube head along with some components of the power supply. All dental X-ray tube are called collidge tubes. The X-ray tube is a glass vacuum tube from which all the air has been removed. The X-ray tube is composed of a lead glass housing, a cathode and an anode (Fig. 2.6).

BASIC COMPONENTS OF AN X-RAY TUBE

Cathode

Lead glass housing is a leaded glass vacuum tube that prevents X-rays from escaping in all directions. The central

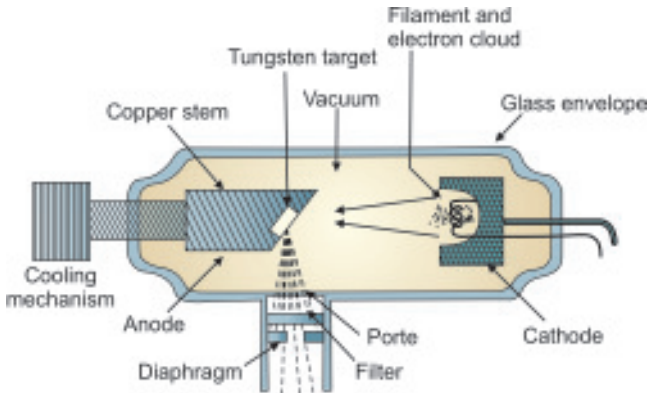


Fig. 2.6: A dental X-ray tube

area of the tube has a window for the exit of the X-ray beam and directs the X-ray beam toward the aluminum disks, lead collimator and PID (Fig. 2.7).

The cathode or negative electrode in an X-ray tube consists of a tungsten wire filament and a focusing cup-shaped holder made of molybdenum. From the cathode side of the tube the

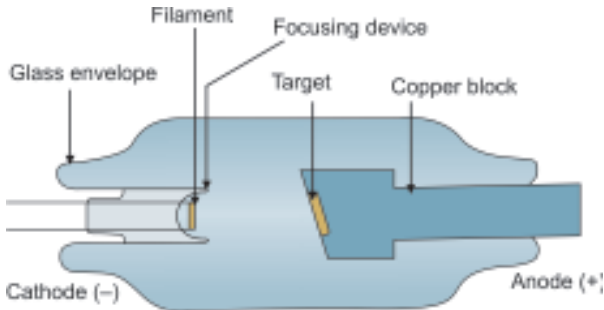


Fig. 2.7: Diagram of a simple X-ray tube showing the main components

electron pass through a focusing cup or area and is directed toward the anode. The cathode consists of:

- (a) *The filament* is a coil of tungsten wire about 2 mm in diameter and 1 cm or less in length, and is the source of electron. The filament is heated by the flow of current from the low-voltage source and emits electrons.
- (b) *The focusing cusp* is a negative charged concave reflector made of molybdenum in which lies the filaments. The focusing as emitted electrons by the filament into a narrow beam directed as a small rectangular area on the anode which is called the focal spot.

Anode

The anode or positive electrode consists of a wafer thin tungsten plate embedded in a copper rod. The purpose of the anode (target) in an X-ray tube is to convert the kinetic energy of the electrons generated from the filament into X-ray photons.

The anode consists of the following:

- (a) *A tungsten target:* Tungsten has a high atomic number (T_d), high melting point, high thermal conductivity and low vapor pressure at the working temperatures of an X-ray tube.

Tungsten target serves as a focal spot. The focal spot is the area on the target to which the focusing cup directs the electrons from the filament. The target is inclined about 20 degree to the central ray of the X-ray beam, this gives the effect of a small apparent source of X-rays and an increase in sharpness of the image with a larger actual focal spot for heat dissipation. This type of anode is a stationary anode (Fig. 2.8).

Rotating anode is another method of dissipating the heat from a small focal spot. In this the electrons strike

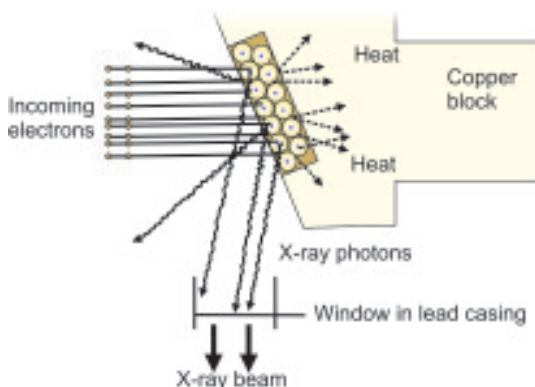


Fig. 2.8: Diagram of the enlarged anode showing the target and summarizing the interaction at the target

successive areas of the target, and thus distributing the heat over this expanded area (Fig. 2.9).

- (b) **The copper stem:** The tungsten target is embedded in a large block of copper to dissipate heat, thus reducing the risk of the target melting.

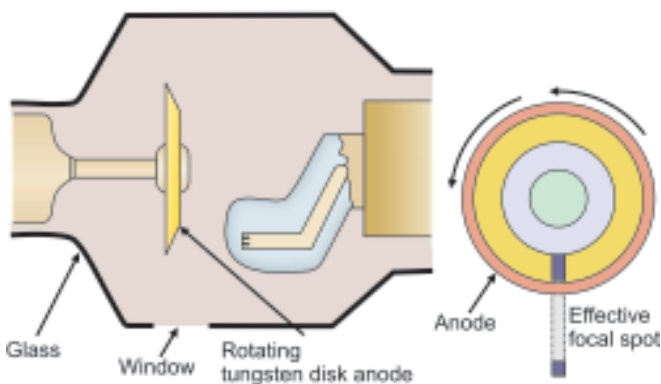


Fig. 2.9: Rotating anode to dissipate heat

X-RAY GENERATING APPARATUS

This includes the electricity, electric currents, electrical circuits and transformers.

Electricity

Electricity is the energy that is used to make X-rays.

Electronic current is the flow of electrons through the tube, that is from the filament to the anode and then back to the filament.

Electric currents are of two types:

- (i) *Direct current*: When the electrons flow in only one direction through the conductor.
- (ii) *Alternating current (AC)*: When the current in which the electrons flow in two opposite directions.

Rectification is the conversion of alternating current to direct current. The dental X-ray tube acts as a self-rectifier and changes AC into DC when producing X-rays.

Rate of current flow: It is the measurement of the number of electrons moving through a conductor. It is measured in amperes or milliamperes (mA).

Voltage: It is the measurement of electrical force that causes electrons to move from a negative pole to a positive pole. It is measured in volt or kilovolts (kV). The kilovolt (kV) is 1000 V.

The amperage and voltage can be adjusted in the X-ray tube for the production of X-rays. In an alternating current where the direction of the current is constantly changing the voltage is also changing and the term kilovolt peak (kVp) is used to denote the maximum or peak voltage that is described by the sine wave that plots the alternation of the current. A dental X-ray machine that is set for a potential of 90 kVp will reach 90 kVp only at the peak of the alternating current during exposure.

By the adjustment on the control panel in the X-ray machine, the number of electrons passing through the cathode filament can be increased or decreased by the milliamperage (mA), and the current passing from the cathode to the anode is controlled by the kilovoltage peak (kVp).

Circuit: It is a path of electrical current (Fig. 2.10).

Two types of electrical currents are needed in the production of X-rays:

- (a) *A low voltage circuit (Primary circuit):* It uses 3 to 5 volts which regulates the flow of electrical current to the filament of the X-ray tube. This is controlled by the milliamperage settings in the control panel.
- (b) *A high voltage circuit (Secondary circuit):* It uses 65,000 to 100,000 volts. A high-voltage circuit is used to accelerate electrons and to generate X-rays in the X-ray tube. This is controlled by the kilovoltage setting in the control panel.

A high voltage is required between the anode and the cathode to generate X-rays.

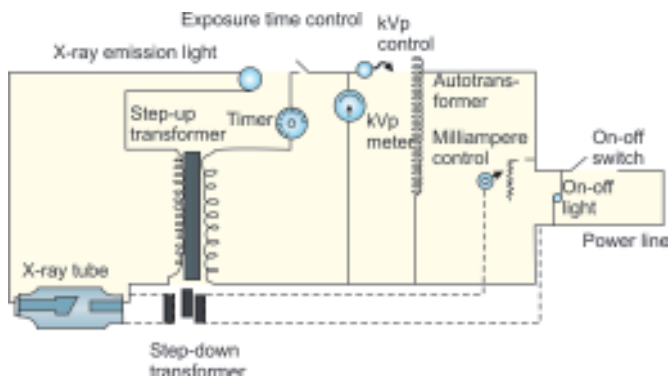


Fig. 2.10: An electric circuit in X-ray machine

TRANSFORMER

Transformer is a device used to increase or decrease the voltage in an electrical circuit. Three types of transformers are used in the dental X-rays to adjust the electrical circuit:

- (a) *Step-down transformer*: Step-down transformer is used to reduce the voltage of the incoming alternating current (AC) to about 10 volts. Its operation is regulated by the milliamperage (mA) switch. Low-voltage circuit regulates the temperature of the filament and thus the number of electrons emitted.
- (b) *Step-up transformer*: This is used to increase the voltage from the incoming 110 or 220 voltage to the 65,000 to 100,000 volts.

Autotransformer

Autotransformer converts the primary voltage from the input source into the secondary voltage. The secondary voltage is regulated by the kilovolts peak (kVp) dial. The kVp dial controls the voltage between the anode and the cathode of the X-ray tube. The high-voltage transformer provides the high voltage required by the X-ray tube to accelerate the electron from the cathode to anode and generates X-rays.

CONTROL PANEL

In clinical practice the control panel is the most common interface of the fluoroscope and the radiographer. From this panel variations in power delivered through the X-ray tube can be controlled for improved images. The milliamperage determines the intensity of the X-ray beam. Kilovoltage determines the speed of the electrons and quality of the X-ray beam. The length of exposure is often measured in second and is the most obvious factor in measuring X-ray exposure.

The milliamperage is important in determining the quantity of X-rays produced. In combination with the length of exposure, the milliamperage is important to the quality of the image produced. For a stop-motion situation, the operator may need to combine a high milliamperage with a short exposure time.

Kilovoltage determines the penetrating ability and quality of the X-ray beam. The higher energy release of X-rays results in a greater number of photons to be captured by the image. This allows for a more detailed and wider range of contrast of the gray scale.

The timer is also located on the control panel. There are audible alerts set at 5-minute intervals to remind the fluoroscopist of the actual time of X-radiation exposure. Exposure is best limited by minimizing fluoroscopy time.

To simplify the measurement of time, the timer should be reset prior to each new procedure. Many of the other buttons available for manual control involve the orientation of the fluoroscopic image from left to right inversion. This function is important for the interventional physician in the performance of the procedure.

Interventional radiology procedures can require substantial amounts of ionizing radiation and, therefore, necessitate particularly close attention to radiation management.

TIMER

In newer dental X-ray machines, the exposure deal are not calibrated in fractions of seconds but more realistically in impulses. On the timer dial '24' means 24 impulses per second, which is equivalent to $2/5$ or $24/60$ second of exposure. Now all machines have electronically controlled timers so that those short exposure times can be achieved accurately and repeatedly.

The X-ray machine should be turned off after use. Warm-up time is almost instantaneous for the X-ray tube, so there is no need to keep the machine on during the work day.

X-RAY BEAM

The X-ray photons produced at the target in the dental X-ray tube emanate from and leave the tube as a divergent beam. The X-ray at the center of the beam is called the central ray. The X-rays closest to the central ray are more parallel and those furthest away are more divergent. The more parallel rays produce less magnification of the image and are more useful.

The X-ray beam is positioned or aimed at the film in the patient's mouth by an open ended device either a rectangle or a cylinder, called a position indicating device (PID). These PIDs should be lead lined to prevent the scatter radiation to escape outside. PIDs are usually 8, 12 or 16 inches long. All dental machines have short 8-inch, plastic, pointed cones as position-indicating devices. The cone is incorrectly used, the proper term is position indicating device. The problem with the pointed plastic cone is the secondary radiation that is produced by the interaction of the primary beam of X-ray photons with the plastic cone. These secondary X-rays increase the long wavelength radiation to the patient's face and degrade the diagnostic image on the film.

When the open ended PID is used, there is no material at the end of the PID with which to interact. Now open ended PID is most commonly used.

BASIC OPERATION OF X-RAY TUBE

Once the electrical signal is sent through the circuitry, the filament is energized to "boil off" electrons as a thermionic

emission. As the increase of kilovolt (peak) passes through the filament the creation of a higher potential difference results in the emission of electrons beyond the "cloud" of electrons that are found in the vicinity of the filament. The attraction of the electrons into the metal anode (+) surface and the following abrupt stopping of the electrons produce X-radiations and heat. Unfortunately, 99% of this energy is converted into undesired heat and less than 1% is converted into X-radiation.

The variation of the kilovoltage affects the speed of the electrons directed at the anode and generates different wavelengths of the X-rays. For example, A shorter wavelength makes the beam more penetrating. A longer wavelength X-ray is less energetic and less penetrating.

Main Features of an X-ray Tube

- **The cathode (negative):** This consists of a heated filament of tungsten that provides the source of electrons.
- **The anode (positive):** This consists of a target (a small piece of tungsten) set into the angled face of a large copper block to allow efficient removal of heat.
- A focusing device aims the stream of electrons at the focal spot on the target.
- A surrounding lead casing absorbs unwanted X-rays as a radiation protection measure to prevent X-rays, which are emitted in all directions.
- Surrounding oil facilitates the removal of heat.

Main Properties and Characteristics of X-rays

1. X-rays are wave packets of energy of electromagnetic radiation that originate at the atomic level.
2. Each wave packet is equivalent to a quantum of energy and is called a photon. The X-ray beam is made up of millions of photons of different energies.

3. X-rays are invisible and are undetectable by any lenses.
4. X-rays have no mass or weight.
5. X-rays travel at the speed of light, i.e. $3 \times 10^8 \text{ m s}^{-1}$.
6. In free space, X-rays travel in straight lines and can be different or scattered.
7. No medium is required for propagation.
8. X-rays can penetrate solids, liquids and gases. The composition of the substance determines whether X-rays penetrate or pass through or are absorbed.
9. X-rays are capable of producing ionization.
10. X-rays of shorter wavelength have greater energy and therefore, can penetrate a greater distance.
11. X-rays of longer wavelength (soft X-rays) have less energy and have little penetrating power.
12. X-rays can effect film emulsion to produce a visual image (the radiograph) and can cause certain salts to fluoresce and to emit light.

COMPTON EFFECT

Compton effect is an absorption and scattering process predominating with higher-energy photons (see Fig. 2.4B).

Stages in Compton Effect

- The incoming X-ray photon interacts with a free or loosely bound outer-shell electron of the tissue atom.
- The outer-shell electron is ejected (the Compton recoil electron) with loss of some energy of the incoming photon, i.e. there is some absorption. The ejected electron

then undergoes further ionizing interactions within the tissue.

- The remainder of the incoming photon energy is deflected or scattered from its original path as a scattered photon.
- The scattered photon then:
 - Undergoes further Compton interaction within the tissues.
 - Undergoes photoelectric interactions within the tissues.
 - Escapes from the tissues. It is these photons that form the scattered radiation.
- Another free electron is captured to achieve atomic stability.

Summary of Production of X-ray

- The filament is electrically heated and a cloud of electrons is produced around the filament.
- The high voltage (potential difference) across the tube accelerates the electrons at very high speed toward the anode.
- The focusing device aims the electron stream at the focal spot on the target.
- The electrons bombard the target and are brought suddenly to rest.
- The energy lost by electrons is transferred into either heat (99%) or X-ray (about 1%).
- The heat produced is removed and dissipated by the copper rod and the surrounding coil.
- The X-rays are emitted in all directions from the target.

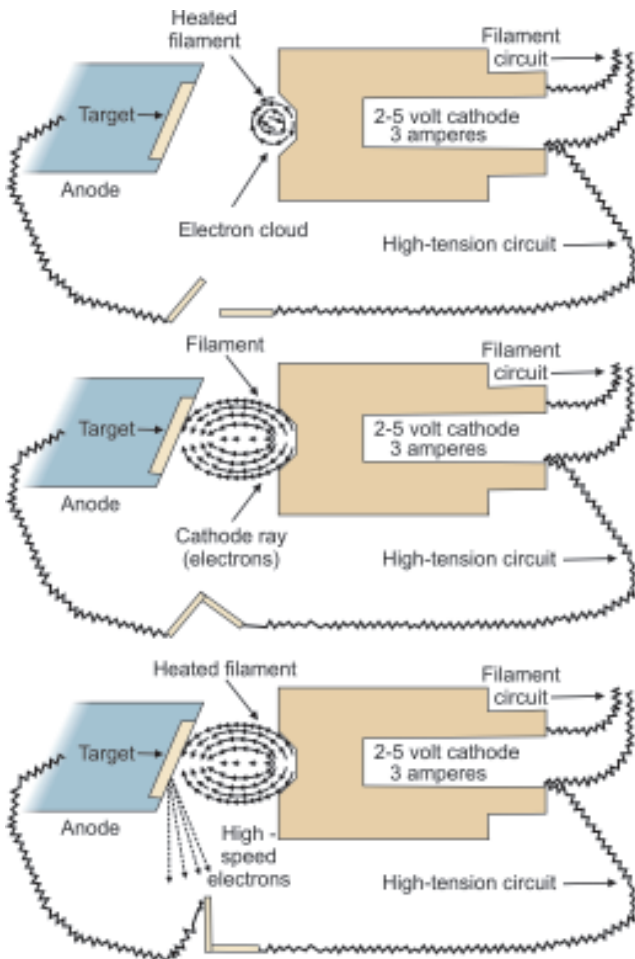


Fig. 2.11: Diagram showing production of X-rays

- The X-rays emitted through the small window in the head casing constitute the beam for diagnostic purposes (Fig. 2.11).

Chapter 3

X-ray Image Characteristics

CHARACTERISTICS OF X-RAY IMAGE

X-ray image characteristics have:

- Visual characteristics.
- Geometric characteristics or projection geometry.

In visual image characteristics include—density and contrast. The geometric image characteristics include—sharpness, magnification and distortion.

DENSITY

The overall degree of darkness or blackness of an exposed film is termed as density. This density can be measured as the optical density of an area of an X-ray film where optical

$$\text{density} = \text{Log}_{10} \frac{I_0}{I_1}$$

I_0 is the intensity of incident light and I_1 is the intensity of the light transmitted through the film.

Measurement of the Opacity of the Film

100% light is transmitted when the optical density is 0, 10% light is transmitted when the density is 1 and 1% light is transmitted when the density is 2.

Characteristic Curve

The relationship between the optical density and the exposure is called characteristic curve. It is usually shown as graph between the optical density of film and the logarithm of the corresponding exposure (Fig. 3.1). As the exposure of the film increases its optical density also increases. The characteristic curve of the film give information about film contrast, speed and latitude. A number of factors directly influence the density of an X-ray film. The density of X-ray film is controlled by

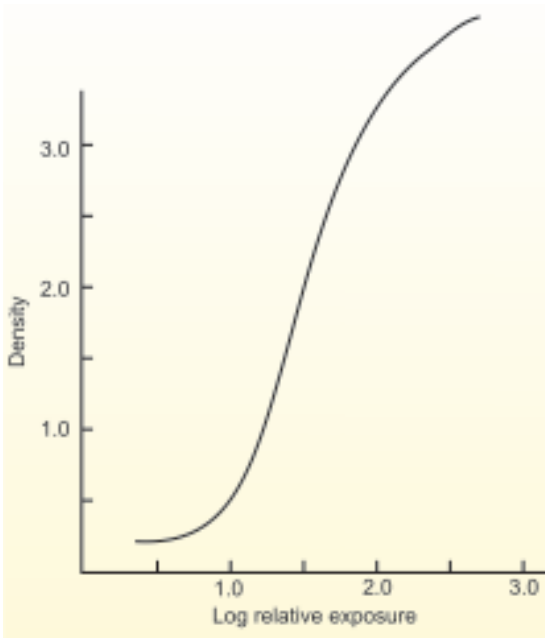


Fig. 3.1: Characteristic curve showing relationship between the optical density and exposure

three-exposure factors, subject thickness and subject density. These three exposure factors are:

- Milliamperage (mA)
- Kilovoltage peak (kVp)
- Exposure time

The film density depends on the number of photons absorbed by the film emulsion. The density of the radiograph increases by increasing the milliamperage (mA), kilovoltage peak (kVp) or exposure time, thus increases the number of photons reaching the film. The film density is also increased by reducing the distance between the focal spot and film.

Milliamperage (mA)

The film density is increased by increasing the milliamperage and thus produces more X-rays that expose the film and the radiograph appears darker (black). Similarly, the film density is decreased by decreasing the milliamperage and the radiograph appears lighter.

Kilovoltage Peak (kVp)

The film density is increased by increasing the kilovoltage which produces X-rays of higher energy and thus the radiograph appears darker. Similarly, the film density is decreased by decreasing to kilovoltage and the radiograph appears lighter.

Exposure Time

Film density is increased by increasing the exposure time and thus the total number of X-rays are increased that reach the film surface and the radiograph appears darker.

Subject Thickness

The thicker the subject, the lighter the resultant image and the more the beam is attenuated. The exposure factors (either kVp or exposure time) can be changed according to the patient's size to produce radiograph of optimal density.

Subject Density

The variations in the density of the subject exert influence on the image of dental film. The greater the density of the structures the greater the attenuation of the X-ray beam directed through that subject. The densities of various structures in oral cavity in decreasing orders are enamel, dentin, cementum, bone, muscle, fat and air. Metallic subjects,

such as amalgam and gold restorations, are far denser than enamel.

Radiopaque Objects

Dense objects cause the radiographic image to be light because of strong absorption of X-rays and thus appear radiopaque.

Radiolucent Objects

Low density objects cause the radiographic image to be dark on the film because of weak absorption of X-rays (photon) and appear radiolucent in the X-ray film.

CONTRAST

Contrast is the difference in the densities between light and dark regions on a dental radiograph.

High Contrast

An image on radiograph showing both light areas and dark areas is said to have high contrast also known as short gray scale of contrast.

Low Contrast

A radiographic image showing light gray and dark gray zones is said to have low contrast also known as a long gray scale of contrast.

The radiographic contrast of an image is the result of subject contrast and film contrast.

Subject Contrast

Subject contrast is the range of characteristics of the subject that influence radiographic contrast, which is determined by

the thickness, density and atomic number of the subject. Subject contrast can be altered by increasing or decreasing the kilovoltage. Mostly operator select a kVp in the range of 70 to 80. When increasing the kVp of the X-ray beam, subject contrast decreases and shades of gray are seen on the dental radiograph. When low kVp is used, subject contrast increases and areas of black and white are seen.

Film Contrast

Film contrast is the capacity of the radiographic films to display differences in subject contrast. This is the characteristic of the film that influences contrast include the inherent qualities of the film and film processing. Film qualities are under the control of the manufacturer and film processing is under the control of the dental radiographer. Film contrast is maximized by optimal film processing conditions. Mishandling of the film by incomplete or excessive development diminishes contrast of anatomic structures. The film contrast is also diminished by improper handling of film such as storage at too high a temperature, exposure to light leaks or using excessively bright safelights in the darkroom and also decrease in development time or the temperature of the developer solution.

Radiographic Speed

Radiographic speed is the amount of radiation required to produce an image of a standard density. Film speed is reciprocal of the exposure required to produce an optical density of 1.

The optical density of 1 is achieved by a fast film requiring low exposure whereas slow film requires a longer exposure.

Film speed is controlled by: (a) the size of the silver halide grains and their silver content. Film speed can be increased by increasing the graininess; (b) Temperature—film speed can be increased by processing the film at higher temperature; (c) processing solutions—use of fresh processing solution increases the film speed. Depleted solutions slower the effective speed; (d) processing time—a recommended processing time should be used. Film speed of dental film is indicated by letters C, D, E and F. The fastest film speed is F of range 48-96 (reciprocal roentgens). For intraoral radiography faster speed film D or more are appropriate. C film has slow speed of range 6-12 (reciprocal roentgens).

Film Latitude

Film latitude is the measurement of range of exposures that are recorded on a film as distinguishable densities.

Wide latitude is required in a film, which can record a subject with a wide range of subject contrast. Wide latitude films are useful when both the osseous structures and soft tissues must be recorded. Film with a wide latitude have lower contrast than the films with a narrow latitude.

A wide latitude and low contrast images can be produced by a high kVp. Wide latitude film is recommended for imaging studies.

Radiographic Noise

Radiographic noise is the appearance of uneven density of a uniformly exposed radiographic film due to localized variations in density.

The causes of noise are:

- Radiographic mottle
- Radiographic artifact

Radiographic mottle is the uneven density due to physical structure of the film such as film graininess or use of fast intensifying screens. Film graininess is evident when high temperature processing is needed.

Radiographic mottle is of two types:

- Quantum mottle
- Screen structure mottle

Quantum mottle is caused by a fluctuation in the number of protons per unit of the beam cross sectional area absorbed by the intensifying screen. It is most evident by use of fast film screen combinations.

Screen structure mottle is graininess caused by screen phosphorus. It is most evident by use of fast screen with larger crystals.

Radiographic Blurring

Radiographic blurring can be prevented by sharpness and resolving power of a radiography.

Sharpness is the ability of a radiograph to define on edge precisely. Resolution (resolution power) is the ability of a radiograph to record separate structures that are close together.

Resolution can be measured by radiographing an object made of a series of thin lead strips with alternating radiolucent spaces of the same thickness. The groups of lines and spaces are arranged in the test target in order of increasing numbers of lines and spaces per millimeter. The resolving power is measured as the highest number of line pairs per millimeter that can be distinguished on the resultant radiograph, when examined with low power magnification.

Causes of radiographic blurring are image receptor, motion blurring and geometric blurring.

Image Receptor Blurring

The sharpness of image is determined by the size and number of the silver grains in the film emulsion, the finer the grain size, the finer the sharpness. Sharpness is fine in slow speed films and having fine grains. Fast films have larger grains.

Image sharpness is diminished by using intensifying screens in extraoral films. Image sharpness is maximized by placing in close contact of intensifying screen and film. The degree of sharpness becomes less because visible light and ultraviolet radiation emitted by the screen spread out beyond the point of origin and expose a film area larger than the phosphor crystal. This spreading light causes blurring of fine detail on the X-ray film.

The image sharpness losses through parallax when the double emulsion film is used. This problem can be solved by incorporating dyes into the base which absorb the high speed radiations emitted by the screens.

Motion Blurring

Image sharpness can be lost through movement of the film, patient or X-ray source during exposure of the film. Patient movement can be minimized by stabilizing the head of the patient with the headrest during the exposure. A shorter exposure time by increasing the mA and kVp also helps to resolve this problem.

Geometric Blurring

Loss of image sharpness is due to several geometric factors such as:

- (a) If photons are not emitted from a point source (focal spot) on the target.

- (b) If larger the focal spot.
- (c) Distance between the object and the image receptor and between the focal spot and the object. The sharpness is improved by increasing the focal spot-object distance and reducing the object-image receptor distance.

PROJECTION GEOMETRY AND IMAGE QUALITY

Projection geometry describes the effect of focal spot size and position relative to the object and film on the image clarity, magnification and distortion.

Image Quality

Image quality and the amount of detail shown on a radiograph depend on several factors which include:

- Contrast
- Image sharpness and resolution
- Image geometry
- Characteristics of the X-ray beam

Contrast

Radiographic contrast, i.e. the final visual difference between the various black, white and gray shadows depends on:

- Subject contrast
- Film contrast
- Fog and scatter

Subject Contrast: This is the difference caused by different degrees of attenuation as the X-ray beam is transmitted through different parts of the patient's tissues. It depends upon:

- Differences in tissue thickness and density.
- Differences in tissue atomic number.
- Quality (kilovolt) or penetrating power of the radiation beam. Subject contrast can be altered by increasing or

decreasing the kilovoltage peak (70 kVp is used for high subject contrast results).

Film Contrast: Film contrast determines how the film will respond to the different exposures which receives after X-ray beam has passed through the patient. Film contrast depends upon:

- The characteristic curve of film.
- Optical density or degree of blackening of the film.
- Type of film direct or indirection action.
- Processing.

The characteristics of the film that influence contrast include the inherent qualities of the film and film processing. The inherent qualities of the film are under the control of the film manufacturer.

Fog and Scatter: Stray radiation reacting the film either as a result of background fog or owing to scatter from within the patient, produces unwanted film density (blackening) and thus reduces radiographic contrast.

Image Sharpness and Resolution

Image sharpness and resolution are important consideration to image clarity.

Sharpness is defined as the ability of the X-ray film to define on edge or boundary between the two areas of differing radiodensity.

When X-ray are produced at the target in an X-ray tube, they originate from all points within the area of the focal spot. Their projections of a feature of an object do not occur at exactly the same location on a film, because these rays originate from different points and travel in straight lines. As a result, the image of the edge of an object is slightly blurred rather than sharp and distinct. This resulting blurred

zone on an image is called the penumbra. This blurring reduces the sharpness and resolution, which result into loss of image clarity (Fig. 3.2).

Thus the main causes of loss of edge definition are:

- Geometric unsharpness which include the penumbra effect.
- Motion unsharpness caused by the patient moving during exposure.
- Absorption unsharpness caused by variation in object shape, e.g. cervical burn out at the neck of a tooth.
- Screen unsharpness caused by the diffusion and spread of the light emitted from intensifying screens.

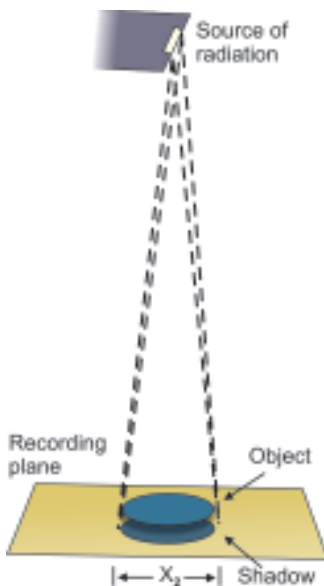


Fig. 3.2: Image penumbra

Resolution or resolving power of the film is a measure of the film's ability to differentiate between different structures and record separate images of small object placed very close together. The resolving power of the film is determined by characteristics of the film such as:

- Type—direct or indirect action
- Speed
- Silver halide emulsion crystal size

Resolution is measured in line pairs per millimeter.

Image Geometry

The loss of image clarity and improvement in the quality of radiographs can be minimized by the following methods:

1. Using as small as effective focal spot as practical.
2. Increasing the distance between the focal spot and the object by using a long, open ended cylinder (Fig. 3.3).
3. Decreasing the distance between the object and the film.
4. The object and the film should be parallel to one another.
5. The X-ray tube head should be positioned so that the beam meets the object and the film at right angles.
1. **Using a small focal spot:** The focal spot size should be of the size 1.0 mm or less in dental X-ray machines. The size of the effective focal spot is a function of the angle of the target with respect to the long axis of the electron beam. A large angle distributes the electron beam over a larger surface and decreases the heat generated per unit of target area. This results in a prolong tube life but into a larger effective focal spot and loss of image clarity. A small angle results in a smaller effective focal spot and decreasing penumbra, but has a greater wearing effect on the target. This decreased penumbra results into

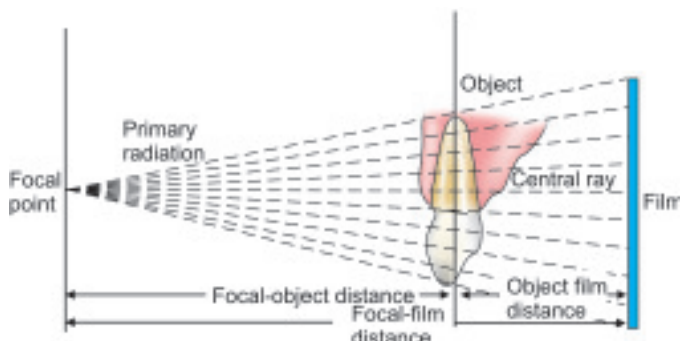


Fig. 3.3: Diagram showing improvement in the quality of image by increasing the focal-object distance or decreasing the object-film distance

increased image sharpness and resolution. The most suitable angle of the face of target to the central X-ray beam is usually between 10 and 20 degrees.

2. ***Increasing the distance between the focal spot and the object:*** The longer focal spot to object distance minimizes blurring by using photons whose paths are almost parallel and thus reducing the divergence of the X-ray beam. This is achieved by using a long open ended cylinders devices in dental X-ray machines (Fig. 3.4).
3. **The distance between the object and the film should be decreased to decrease the penumbra resulting in increased image clarity (Fig. 3.5).**

Characteristics of the X-ray Beam

The ideal X-ray beam used for imaging should have:

- Sufficient penetrating power to pass through the patient to a varying degree and react with the film emulsion to

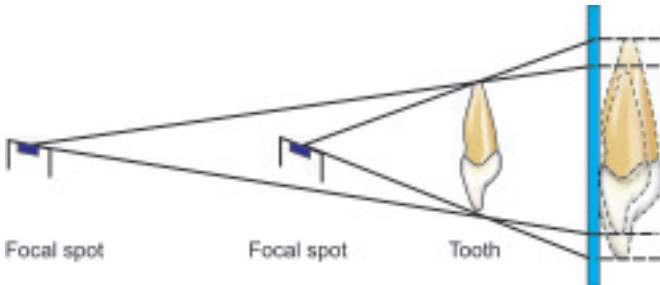


Fig. 3.4: Using a long ended cylinder reduces the blurring

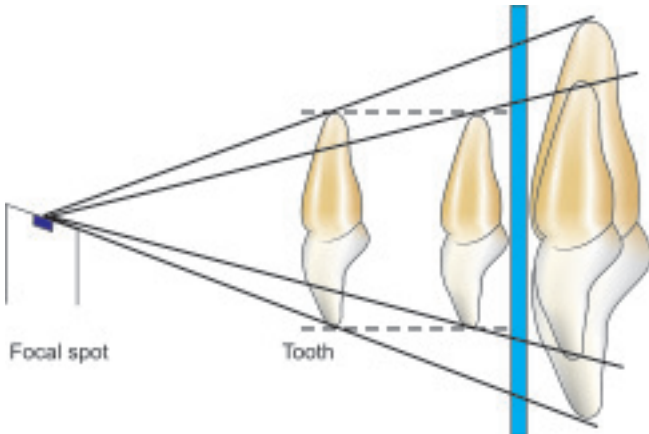


Fig. 3.5: The object and film distance are decreased to reduce the penumbra

produce good contrast between various black, white and gray shadows.

- Parallel, non-diverging beam to prevent magnification of the image.
- Should be produced from a point source to reduce blurring of the image margins.

Magnification of the Image Size (Distortion)

Magnification is the increase in the size of the image on the radiograph when compare it with the actual size of the object. The divergent path of photons in the X-ray beam cause enlargement of the image on a radiograph. Image size distortion results from the relative distances of the focal spot to film and object to film. The image magnification is minimized by increasing the focal spot to film distance and decreasing the object to film distance. Thus the magnification of images on a periapical radiograph can be reduced by using a long, open ended cylinder device in an X-ray machine.

Distortion of the Image Shapes

Distortion of the image shape is due to unequal magnification of different parts of the same object. This is because of the reason that no all parts of an object are at the same focal spot to object distance. The distortion of shape can be minimized by the following:

- a. The film should be positioned parallel to the long axis of the object.
- b. The central ray should be oriented perpendicular to the object and film.

If the central ray is not directed at right angle to the object and film, image shape distortion can occur. This is especially in case of maxillary molar projections, the palatal root appear longer than the buccal roots if the central ray is oriented with an excessive angulation.

Two types of shape distortion can occur:

Foreshortening: In this the radiographic image is shorter than the object. This is when the central X-ray beam is perpendicular to the film, but the object is not parallel to the film and the resultant image is distorted because of the unequal distances of the various parts of the object from the film.

Elongation: In this the object is appearing longer on the film than its actual length. This situation is when X-ray beam is oriented at right angles to the object but not the film.

A radiograph should have a good image quality, less image size distortion (magnification) and minimal image shape distortion.

Image quality will give improvement in the amount of detail. Less image size and shape distortion are important for an accurate radiograph.

Coherent Scattering

When a low-energy incident photon passes near an outer electron of atom (having a low binding energy), coherent scattering may occur. The photon may be scattered without a loss of energy and are not absorbed (Fig. 3.6).

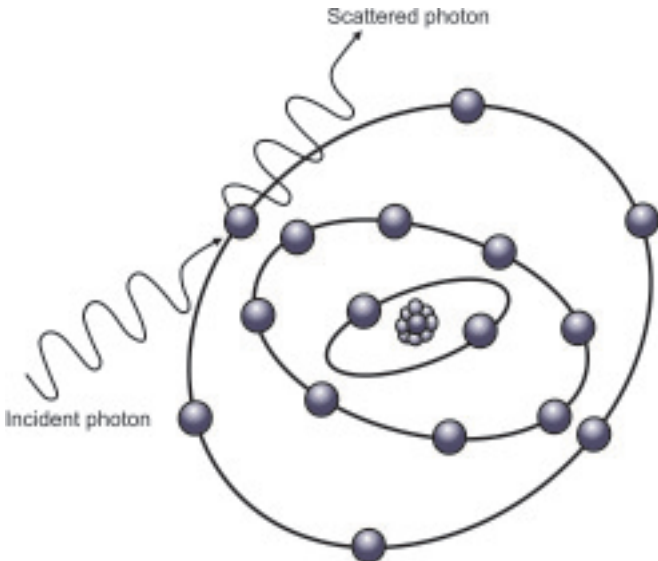


Fig. 3.6: Diagram showing coherent scattering

The incident photon interacts with the electron by causing vibrate momentarily at the same frequency as the incoming photon. The incident photon then chooses to exist. The vibration causes the electron to radiate energy in the form of another X-ray photon with the same frequency and energy as in the incident beam. The direction of the incident X-ray photon is altered because the secondary photon is emitted at an angle to the path of the incident photon. Since the total quantity of scattered photons is small and its energy level is too low to reach the film it causes very little to film fog.

Chapter 4

Dose Units and Dosimetry

Dosimetry is the determination of the quantity of radiation exposure or dose.

Dose is the amount of energy absorbed per unit mass at a site of interest.

Exposure is the measurement of radiation based on its ability to produce ionization in air. The roentgen (R) is the original unit if radiation exposure measured in air.

1R is the amounting X-radiation that produces 2.08×10^9 ion pairs in 1 cc of air. This is the measure of intensity of radiation to which an object is exposed.

RADIATION-ABSORBED DOSE (D)

This is a measure of the amount of energy absorbed from the radiation beam per unit mass of tissue.

SI Unit—Gray (Gy), measured in joules/kg

Subunit—Milligray (mGy) ($\times 10^{-3}$)

Original Unit—Rad, measured in ergs/g

Conversion—1 Gray = 100 rads

EQUIVALENT DOSE (H)

This is a measure which allows the different radiobiological effectiveness of different types of radiation to be taken into account.

The biological effect of a particular radiation—absorbed dose of alpha particles are considerably more severe than a similar radiation—absorbed dose of X-rays because alpha particles penetrate only a few millimeters in tissue, lose all their energy and are totally absorbed whereas X-rays penetrate much further, lose some of their energy and are only partially absorbed.

Radiation weighting factor W_R represents the biological effects of different radiations.

X-rays, gamma rays and beta particles $W_R=1$

Fast neutrons (10 KeV - 100 KeV)

Protons $W_R = 10$

Alpha particles $W_R = 20$

Equivalent dose (H) = radiation-absorbed dose (D) $\times$ radiation weighting factor (W_R)

SI Unit : Sievert (Sv)

Subunit : millisievert (mSv) ($\times 10^{-3}$)

: microsievert (μ Sv) ($\times 10^{-6}$)

Original unit : rem

Conversion : 1 sievert = 100 rems

For X-rays, the radiation weighting factor (W_R factor) = 1, therefore, the equivalent dose (H), measured in Sievert, is equal to the radiation—absorbed dose (D) which is measured in Grays.

Effective Dose (E)

This measure allows doses from different investigations of different parts of the body to be compared by converting all doses to an equivalent whole body dose. This is necessary because some parts of the body are more sensitive to radiation than others. The International Commission on Radiological Protection (ICRP) has allocated each tissue a numerical value, known as the tissue weighting factor (W_T) based on its radiosensitivity, i.e. the risk of the tissue being damaged by radiation, the greater the risk, the higher the tissue weighting factor. The sum of the individual tissue weighting factors represents the weighting factor for the whole body.

Effective Dose (E) = equivalent dose (H) $\times$ tissue weighting factor (W_T)

SI Unit : Sievert (Sv)

Subunit : millisievert (mSv)

When the term dose is applied which means it is the effective dose (E). Thus effective dose is the indication of the risk to health from any exposure to ionizing radiation, irrespective of the type or energy of the radiation or the part of the body being irradiated.

Collective Effective Dose or Collective Dose

This measure is used when considering the total effective dose to a population from a source of radiation.

Collective dose = effective dose (E) $\times$ population.

SI Unit : man-sievert (man-Sv)

Dose Rate

This is a measure of the dose per unit time, e.g. dose/hour.

SI Unit : microsievert/hour ($\mu\text{Sv h}^{-1}$)

Annual Doses from Various Sources of Radiation

Every individual is exposed to some form of ionizing radiation from the environment where we live. These sources are:

1. Natural radiation:
 - Cosmic radiation from the earth's atmosphere.
 - Gamma radiated from the rocks and soil in the earth's crust.
 - Radiation from ingested radioisotopes, e.g. 40K (in certain foods).
 - Radon and its decay products. Radon as a gas diffuses readily from rocks through soil and can be trapped in poorly ventilated houses and then breathed into the lungs.
2. Artificial radiation:
 - Fallout from nuclear explosives.
 - Radioactive waste.
3. Medical and dental diagnostics radiation.
4. Radiation from occupational exposure—An individual's average dose from these radiation is estimated at approximately 2.7 μSv to 3.6 μSv per year.

Dose from these sources of radiation is estimated at approximately 203.6 mSv per year. The individual doses encountered in dental radiology may appear very small but consider the additional radiation burden, which the patient is already receiving from the sources of radiation. This additional dose may be considerable for any individual patient.

Chapter 5

Biological Effects

RADIATION HAZARDS

Principle of Radiobiology

Radiobiology has progressed from the description of cellular and tissue response to radiation to the characterization of genes and proteins that can influence these responses. The important features of the cellular response are ionizing radiation and to incorporate the recent developments in our understanding of the underlying molecular mechanisms.

Radiation hazards occur as a result of damage to cell caused by radiation. This damage takes the following different forms:

Cell Death

- Mitotic inhibition (temporary/permanent).
- Chromosome damage/genetic damage leading to mutations.
- Actively dividing cells are particularly sensitive (e.g. bone marrow, lymph glands, gonads).

The nature and degree of cell damage vary according to:

- Radiation dose
- Dose rate
- Irradiated volume
- Type of radiation

In general, two types of effects are seen as a result of radiation damage:

Stochastic Effects

- Probability of effects, not severity, regarded as a function of dose.
- No dose threshold below which an effect will not theoretically occur.
- Due to modified cell, e.g. somatic cell leading to cancers; reproduction cell leading to hereditary effects.

Deterministic Effects

- Severity of effects varies with dose.
- Dose threshold may exist below which the effect will not occur.
- Due to cell death, deterministic effects occur when cell loss is sufficient to impair organ function (e.g. radiation burns, cataracts and decreased fertility).

The biological damaging effects of ionizing radiation are classified into three main categories:

- Somatic deterministic effects.
- Somatic stochastic effects.
- Genetic stochastic effects.

The somatic effects can be divided into:

(1) Immediate effects (Acute effects) appearing shortly after exposure, e.g. as a result of large whole body doses, such as slight blood changes, e.g. decrease in white blood cell count, vomiting, fatigue, loss of appetite, loss of hair, brain damage. (2) Acute effect of radiation result from high doses of whole body radiation, usually more than 100 rad. (3) The clinical effects of the exposure which may vary from mild and transient illness to death may occur minutes, hours or weeks after the acute exposure. The lethal whole body dose for humans is 450 rod. (4) Long-term effects (chronic effects) evident after a large period of time, the so-called latent period (20 years or more), e.g. leukemia. Acute and/or chronic exposure may produce effects on the somatic cells as well as have genetic effects in future generations.

Somatic Deterministic Effects

A specific high-dose of radiation definitely results the damaging effects to the body of the person exposed to radiation, e.g. redness of the skin and cataract formation. The severity of the effect is proportional to the dose received,

and a threshold dose exists below which there will be no effects.

Somatic Stochastic Effects

Stochastic effects are those that may develop spontaneously. Their development is random and depends on the laws of chance of probability. Examples: leukemia and certain tumors.

These damaging effects may be induced when the body is exposed to any dose of radiation. It is not possible to establish a safe dose below which stochastic effects do not develop. Hence there is no threshold dose and every exposure to ionizing radiation carries with it the possibility of inducing a stochastic effect.

Genetic Stochastic Effects

Mutation results from any sudden change to a gene or chromosome. They can be caused by external factors, such as a radiation, or may occur spontaneously.

Radiation to the reproductive organs may damage the DNA of the sperm or egg cells. This may result in a congenital abnormalities in the offspring of the person irradiated. All genetic effects are described as stochastic as there is no certainty that these effects will happen. It is estimated that a dose of 0.5 to 1.0 Sv to the gonads would double the spontaneous mutation rate. There is no threshold dose.

Effects on the Unborn Child

The developing fetus is particularly sensitive to the effects of radiation, especially during the period of organogenesis (2-9 weeks after conception).

The main problems are:

- Congenital abnormalities or death associated with large doses of radiation.
- Mental retardation associated with low doses of radiation.

HARMFUL EFFECTS IN DENTAL RADIOLOGY

In dentistry, the size of the doses used routinely are relatively small and well below the threshold doses required to produce the somatic deterministic effects. However, somatic and genetic stochastic effect can develop with any dose of ionizing radiation. Dental radiology does not usually involve irradiating the reproductive organs, thus in dentistry somatic stochastic effects are the damaging effects of most concern.

Latent Period

The latent period is the time that elapses between the exposure to ionizing radiation and the appearance of clinical symptoms. This time depends on the magnitude of exposure and the tissue involved. All radiation-induced changes in tissue cells are not permanent. Depending on the time interval, dose and sensitivity of the affected cells to radiation, the cells repair processes may be sufficient to effect cell recovery from the radiation.

DAMAGING EFFECTS OF RADIATION

The following two main mechanisms are responsible for damage:

Direct Damage

This is the direct damage to specific targets within the cell, such as chromosomal DNA or RNA in the nucleus. These

structures take a direct hit from an incoming X-ray photon or an ejected high-energy electron, which breaks the relatively weak bonds between the nucleic acids.

The chromosomal effects which result include:

- Abnormal replication
- Inability to pass an information
- Cellular death
- Sometimes only temporary damage—the DNA being repaired successfully before further cell division.

If the radiation hits somatic cells, it could result in a radiation-induced malignancy and, if the damage is to reproductive stem cells, the result could be a radiation-induced congenital abnormalities.

The factors which causes cell damage are:

- a. The type and number of nucleic acid bonds that are broken.
- b. The intensity and type of radiation.
- c. The time between exposures.
- d. The ability of the cell to repair the damage.
- e. The stage of cells reproductive cycle when irradiated.

Indirect Damage

The water molecules which is present in about 75% of the cell contents are most likely to be ionized by the incoming X-ray. The damage to the cell results from the free radicals which are produced by the ionization process. The following is the process of breakdown of H_2O present in the cell:

Radiation

1. $\text{H}_2\text{O} \rightarrow \text{H}_2\text{O}^+ + \text{e}^-$
2. The positive ion immediately breaks up:
 $\text{H}_2\text{O}^+ \rightarrow \text{H}^+ + \text{OH}^-$

3. The electron (e^-) attaches to a neutral water molecule:
$$\text{H}_2\text{O} + e^- \rightarrow \text{H}_2\text{O}^-$$
4. The resulting negatively charged molecule dissociates:
$$\text{H}_2\text{O}^- \rightarrow \text{H}^+ + \text{OH}^-$$
5. The electrically neutral H and OH are unstable and highly reactive and are called free radicals. They can combine with other free radicals. Examples:
$$\text{H} + \text{H} \rightarrow \text{H}_2 \text{ (hydrogen gas)}$$
$$\text{OH} + \text{OH} \rightarrow \text{H}_2\text{O}_2 \text{ (hydrogen peroxide)}$$

The hydrogen peroxide can then DAMAGE the cell by breaking down large molecules like proteins or DNA.

Radiation-induced Subcellular Damage

Ionizing radiation transfers energy to the molecules with which it interacts. This leads to ejection of an electron at the atomic level which then reacts with other atoms, causing secondary ionizations. The main product of this process in a cell is an ionized water molecule H_2O^+ which can interact with another water molecule to form OH radicals. These OH radicals have a very high reactivity. Reducing species H and e^- are also formed. All these reactive species can go on to damage other molecules, especially DNA, in the so-called indirect effect. Direct damage is the product of ionizations within the chromatin.

Radiation causes a wide range of types of damage in DNA such as strand breaks, base or sugar damage and cross links between macromolecules (i.e. DNA-DNA or DNA-protein cross links). In general, the DNA double strand break is the most critical for the lethal effects of radiation.

Chromosome and Chromatic Aberrations

When cells are irradiated in the G phase of the cell cycle, the product of DNA damage is observed as chromosome

aberrations or when the cells are irradiated after the DNA replication phase the chromatid aberrations are observed. Frank breaks in chromosome are commonly induced, and aberrations involving breakage and rejoining of chromosome fragments (e.g. translocations and ring formation) are observed in many irradiated cells. There is a direct relationship between cell death and chromosome aberration. Damage is an important aspect of the radiation-induced killing of many cells.

Oxygen Effect

Oxygen is important to the effects of irradiation. Cells that are irradiated in the absence of oxygen are much more resistant to radiation than those irradiated in oxygen. This is due to the oxygen molecules reacting with free radicals to produce chemically unrepairable peroxyradicals ($R + O_2 = RO_2$). Thus in effectoxic cells suffer more DNA damage. The degree of sensitization by oxygen is often quoted as an oxygen enhancement ratio (OER), which is the ratio of doses needed to produce a given biological effect in the presence or absence of oxygen. For most cells and tissues the OSR has the value of around 2.5-3.

Recent experiments have shown that the proportion of the tumor that is deficient in oxygen can have an important influence on the success of radiotherapy. It is important to make sure that patients are not anemic when they start radiotherapy. The patient breathes oxygen at up to three times atmospheric pressure (hyperbaric oxygen, HBO) during irradiations (Fig. 5.1).

Reoxygenation

A lack of oxygen can severely limit the cytotoxicity of radiation and the presence of hypoxic cells in a tumor can therefore be

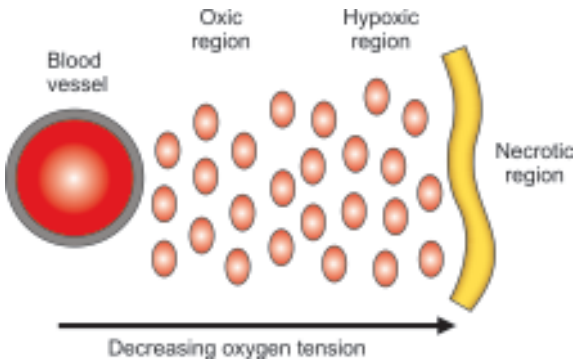


Fig. 5.1: Oxygen gradient away from a vessel. Oxygen generally diffuses a distance of around 200 mm from a blood vessel. Beyond this distance, viable oxic cells are first encountered, then hypoxic regions containing dead cells form necrotic regions

limiting to the success of radiotherapy. One positive aspect of fractionating radiotherapy is that cells that survive one treatment because of a hypoxic environment may become reoxygenated before the next treatment. Again this is a result of loss of the killed cells leading to a better oxygen supply to the survivors.

Radiation-induced Cell Killing

The biological effect of radiation is the ability to limit the proliferation of cells that would normally divide and produce several daughter cells. In some normal tissues the key targets are the stem cells that form the proliferative driving force of a tissue in that they have an unlimited ability to divide. In tumors there may also be a subset of cells that make the major contribution to tumor growth. The directing of cell down a differentiation pathway or its existence in a

region of low-nutrient supply may take cells out of this proliferating compartment.

Biological Effects of Radiation

A variety of injuries or damages can result from excessive doses of ionizing radiation. The following are the effects:

- Injuries to the skin arising from exposure of the epidermis to radiations of low penetrating power.
- Changes in the blood forming organs and the number and nature of the circulating blood cells.
- Cancer produced by exposure to radiation arising from either external or internal sources of radiation.
- Genetic effects arising from the production of mutations by the irradiation of the reproductive system.
- Cataract formation due to irradiation of the lens of the eye by radiation of low penetrating power.

Earlier Radiation Damage

The damage suffered by the early radiologists was of two types:

1. Damage to the tissues of the hands resulting from exposure to the direct beam of X-rays. The damage was often very serious and sometimes fatal.
2. Damage to the hemopoietic system—the site of blood cell formation in the bone marrow—by exposure of the whole body to scattered radiation over long periods or the ingestion of radionuclides.

Radiation Effects at Low Doses

The addition of man-made sources of ionizing radiation to the environmental sources will give rise to an increase in both incidence of malignant disease and genetic abnormalities.

The effects of ionizing radiation begin with the ionization of an atom or molecule within a cell. The cell is not necessarily damaged. If it is slightly damaged, the damage may be repaired by the body's defence mechanism. If it is severely damaged, it may die or it may go on proliferating in a modified form, and after a latent period, produce a cancer. These effects are very much chance effect, starting from the ionization of a single cell. These chance effects can be described by the technical term stochastic and where the effect is manifested in the person exposed, the effect is said to be somatic.

When the damage cells belong to the reproductive system (germ cells), they may be responsible for passing of incorrect hereditary information to the next generation. Such genetic defects may be trivial or may lead to serious disability or even death. However, these effects are experimental on plant and animals; there is little evidence in man.

The effects of radiation on an embryo are very dependent on its stage of development. At the early stages, there are few cells involved and exposure to radiation is likely to cause an undetectable death of the embryo rather than result in stochastic effects in the live-born. After the third week, radiation may increase the probability of cancer or organ malformation. There may be a shift downward in IQ, with the shift increasing with dose. 8-15 weeks are the most sensitive period for mental retardation. After 16th week of pregnancy this shift seems to be smaller.

Effective Dose Limits

The latest recommendation by International Council of Radiation Protection (ICRP), 1991 is that while the annual limit is 50 μSv , the dose averaged over any 5 years period should not exceed 20 μSv per year for those occupationally exposed

and over 18 years of age. Women of reproductive capacity at work are subject to the further constraint that the equivalent dose from external radiation shall not exceed $14 \mu\text{Sv}$ in any consecutive period of 3 months. Radiation workers under 18 years of age are subject to a limit of $6 \mu\text{Sv}$ in any calendar year. It is also proposed to ban all persons under 16 years of age from working with ionizing radiations.

All those not occupationally exposed (e.g. other staff, patient's attendant, visitors, etc.) are subjected to the lower 'public' dose limit of $1 \mu\text{Sv}$ in any calendar year averaged over 5 years subjects to maximum of $5 \mu\text{Sv}$ in 1 year.

There is no distinction between men and women. Once a pregnancy has been confirmed, an effective dose limit to the surface of women's abdomen of $2 \mu\text{Sv}$ is applied for the remainder of the pregnancy.

BASIC PRINCIPLES OF PROTECTION

The following principles of dose limitation should be in practice to come to a compromise as to the most effective means of minimizing radiation hazard.

Time

Total exposure is the product of exposure rate and time and therefore, it is important to keep the exposure time as short as possible, but consistent with the desired clinical result as any further reduction may jeopardize the outcome and result in further exposure. Fluoroscopy screening times in diagnosis or treatment simulation may be kept short by the use of last frame hold facilities.

Distance

The intensity of radiation and the exposure rate are reduced with increasing distance from the source, following the inverse

square law, where patients have sources *in situ*, standing at 3 meters distance is more than twice as effective as standing at 2 meters.

Barriers

An appropriate protective barrier should be used between the source of radiation and the patient or staff. The shielding is of a material appropriate to protect the radiation. A simple Perspex shield can be very effective against beta particles. A lead rubber apron is ineffective against the photons from cesium or irradium. Lead glass spectacles may be usefully employed for screening procedures which require manipulation of the patients, but the hands must be kept well out of the primary beam as lead rubber gloves give limited protection. Aprons must be worn and fastened and the use of thyroid shields by staff is to be encouraged to protect them from scattered radiation. Gonad shields are of course essential for the patient (Fig. 5.2).

A careful design of protected walls, benches, etc. are encouraged for protection.

The presence of ionizing radiation cannot be detected by any of the five human senses and no instrument can detect the whole range of ionizing radiation. The instrument for detection should be carefully chosen.

Radiation trefoil signs will be displayed in any situation where there might be a radiation hazard or where special precautions are required.

Protection of Radiological Practice

Aims and principles of radiation are:

- To prevent deterministic effects.
- To limit the probability of stochastic effects of keeping all justifiable exposure as low as in reasonably achievable

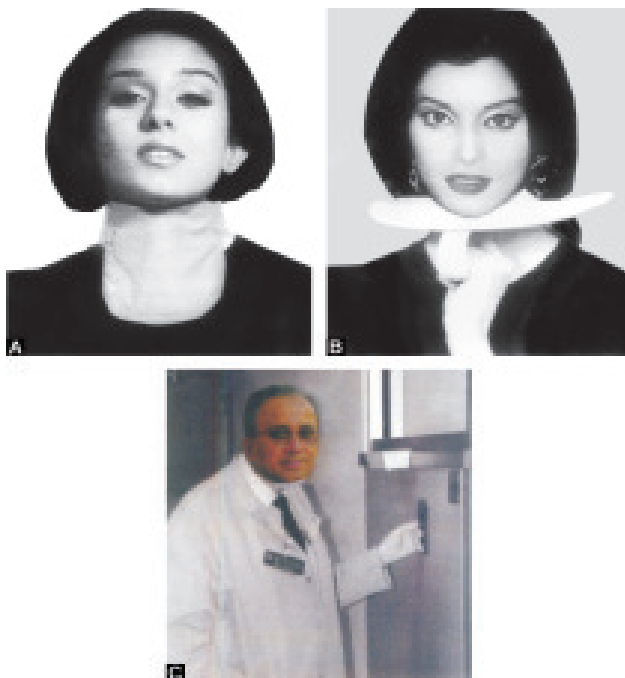


Fig. 5.2: Protective shield used by the patients: (A) Thyroid lead protection lead collar, (B) Hand-held neck shield, (C) Operator making exposure while wearing gloves and protective clothing

(ALARA principle), this includes keeping as low as possible doses to individuals, the number of people exposed and the likelihood of others being exposed.

- No practice is adopted unless its introduction produces a benefit that outweighs its detriment, i.e. positive net benefit.

The following guidelines are used for radiographic procedures:

Protection of Patients

- Each exposure justified on a case-by-case basis.
- Minimize number of X-ray films taken as well as screening time.
- Focus beam accurately to area of interest.
- Only trained personnel to operate equipment.
- Good equipment to be used including rare earth screens, adequate filtration of X-ray beams, etc.
- Minimize the use of mobile equipment. Use ultrasound or MRI where possible.
- Quality assurance programs in each department, including correct installation, calibration and regular testing of equipment.

Pediatrics

- Special attention to minimizing number of exposure, screening times and the use of well-focused beams.
- Use of restraining devices and/or sedation. Gonad shields.
- If parents are required in the room, they should wear lead coats and not be directly exposed to radiation.

Women of Reproductive Age

- Minimize radiation exposure of abdomen and pelvis.
- Consider any woman of reproductive age whose period is overdue to be pregnant.
- Ask all females of reproductive age if they could be pregnant.
- Post-multilingual signs in prominent places asking patients to notify the radiographer of possible pregnancy.

Pregnancy

- As organogenesis is unlikely to be occurring in an embryo in the first 4 weeks following the last menstrual period, this is not considered a critical period for radiation exposure.
- Organogenesis commences soon after the time of the first missed period and continues for the next 3-4 months; hence during this time the fetus is considered to be radiosensitive.

Chapter 6

Factors Controlling X-ray Beam

The X-ray beam emitted from an X-ray tube may be modified by altering the beam exposure length (timer), exposure rate (mA) beam energy (kVp and filtration), beam shape (collimation) and target-patient distance.

EXPOSURE TIME

There are changes in the X-ray spectrum that result when the exposure time is increased while the tube current (mA) and voltage (kVp) remain constant. When the exposure time is doubled, the number of photons generated at all energies in the X-ray emission spectrum is doubled, but the range of photon energies is unchanged. Therefore, changing the time simply controls the quantity of the exposure, the number of photons generated.

TUBE CURRENT (mA)

There are changes in the spectrum of photons that result from increasing tube current (mA) exposure time. As the mA setting is increased, more power is applied to the filament, which heats up and releases more electrons that collide with the target to produce radiation. Therefore, the quantity of radiation produced by an X-ray tube (i.e. the number of photons that reaches the patient and film) is directly proportional to the tube current (mA) and the time the tube is operated. The quantity of radiation produced is expressed as the product of time and tube current. The quantity of radiation remains constant regardless of variation in mA and time as long as their product remains constant. For instance, a machine operating at 10 mA for 1 second (10 mAs) produces the same quantity of radiation when operated at 20 mA for 0.5 second (10 mAs) although in practice some dental X-ray machines fall slightly short of this ideal constancy.

TUBE VOLTAGE (kVp)

Increasing the kVp increases the potential difference between the cathode and the anode, thus increasing the energy of each electron when it strikes the target. This results in an increased efficiency of conversion of electron energy into X-ray photons, and thus an increase in (1) the number of photons generated, (2) their mean energy and (3) their maximal energy. The increased number of photons produced per unit time by use of higher kVp results from the greater efficiency in the production of bremsstrahlung photons that occur when increased numbers of higher-energy electrons interact with the target.

The ability of X-ray photons to penetrate matter depends on their energy. High-energy X-ray photons have a greater probability of penetrating matter, whereas relatively low-energy photons have a greater probability of being absorbed. Therefore, the higher the kVp and mean energy of the X-ray beam, the greater the penetrability of the beam through matter. A useful way to characterize the penetrating quality of an X-ray beam (its energy) is by its half-value layer (HVL). The HVL is the thickness of an absorber, such as aluminum, required to reduce by one half the number of X-ray photons passing through it. As the average energy of an X-ray beam increases so does its HVL. The term beam quality refers to the mean energy of an X-ray beam.

FILTRATION

Although an X-ray beam consists of a spectrum of X-ray photons of different energies, only photons with sufficient energy to penetrate through anatomic structures and reach the image receptor (usually film) are useful for diagnosis. Total filtration is the sum of the inherent filtration plus any added external filtration supplied in the form of aluminum

disks placed over the port in the head of the X-ray machine. Total filtration in the path of dental X-ray beam to be equal to the equivalent of 1.5 mm of aluminum to 70 kVp and 2.5 mm of aluminum for all higher voltages.

COLLIMATION

The collimating devices (Fig. 6.1) most often used are a lead diaphragm with a circular aperture and the metallic PID. The size of this aperture, at a selected FFD, determines the beam size. PIDs, be they open ended cylinder or rectangular, lead lined or made of metal also can serve as collimating devices (Fig. 6.2). Circular collimation allows a margin of error in film beam alignment. To protect the patients skin, the size of X-ray beam should not exceed $2\frac{3}{4}$ inches (7 cm) in diameter.

A collimator is a metallic barrier with an aperture in the middle used to reduce the size of the X-ray beam and, therefore, the volume of irradiated tissue within the patient.

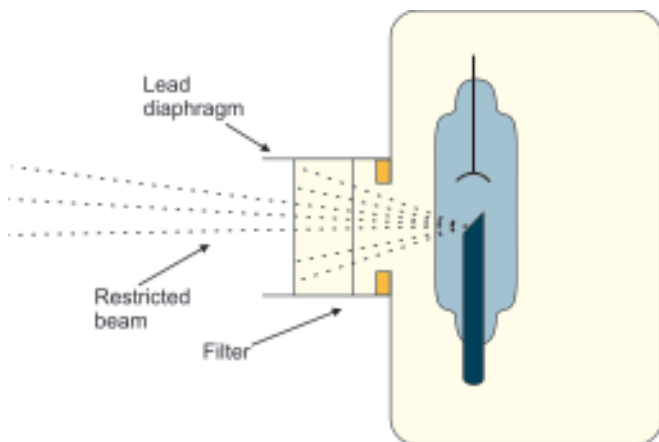


Fig. 6.1: Collimation of X-ray beam

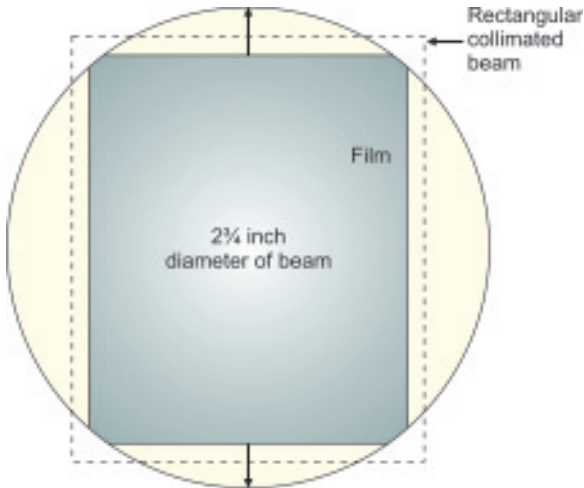


Fig. 6.2: Relative size of adult film packet compared with X-ray beam $2\frac{3}{4}$ inches (7 cm) in diameter and rectangularly collimated beam

Circular and rectangular collimators are most frequently used in dentistry. Dental X-ray beams are usually collimated to a circle $2\frac{3}{4}$ inches (7 cm) in diameter. A circular collimator is a thick plate of radiopaque material (usually lead) ray head through which the X-ray beam emerges. Typically circular collimators are built into open-ended aiming cylinders. In rectangular collimators aiming cylinders, it is important to reduce the beam to the size of the film to reduce further unnecessary patient exposure.

Use of collimation also improves image quality. When an X-ray beam is directed at a patient, the tissues absorb about 90% of the X-ray photons and 10% of the photons pass through the patient and reach the film. Many of the absorbed photons generate scattered radiation within the exposed tissues by a process called Compton scattering. These scattered photons travel in all directions, and some reach the film and degrade

image quality. Collimation of the beam to reduce the exposure area and thus the number of scattered photons reaching the film can minimize the detrimental effect of scattered radiation on the images.

X-ray Beam

The X-ray beam is a divergent beam. The center of this X-ray beam is called the central ray. The X-rays close to the central ray are parallel and those farther away are divergent. The X-rays which are more parallel produce less magnifications of the image and thus they are more useful (Fig. 6.3).

The X-ray beam is positioned or aimed at the film in the patient's mouth by an open-ended device, either a rectangle or a cylinder, called a position indicating device (PID). These PID are lead lined to prevent the escape of scattered radiation; PID are usually 8, 12 or 16 inches long. All dental machines have a short, 8 inches, plastic pointed cones as position indicating device. The tip of the pointed cone indicates the position of the

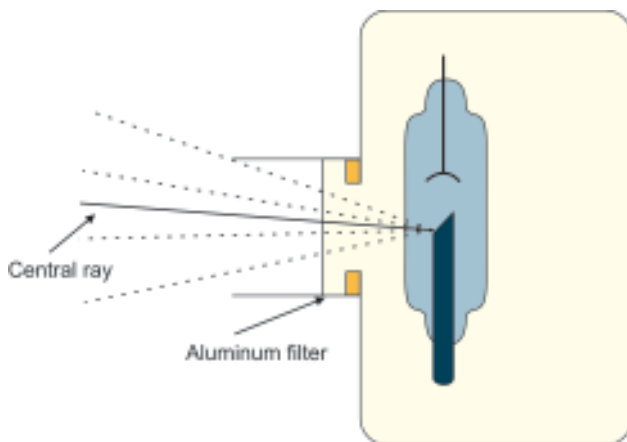


Fig. 6.3: The divergent X-ray beam. The aluminum filter removes longer wavelength X-rays from the X-ray beam

central ray. The pointed cone is useful for assuring the tip of the cone at the center of the film placed in the patient's mouth or as the extraoral anatomical landmark.

The problem with pointed plastic cone is the secondary radiation that is produced by the interaction of the primary beam of X-ray photons with the plastic cone. These secondary radiations increase the long-wavelength radiation to the patient's face and degrade the diagnostic image on the film (Fig. 6.4).

The X-rays interact with the plastic present in the pointed cone. X-rays interact and cause secondary radiation with any form of matter such as a piece of tissue paper to a bar of steel. Density of the material and the quality of the X-ray beam determine the type and extent of interaction.

Nowadays for these disadvantages of the pointed plastic cones, the open ended PID is used. In this no material is present

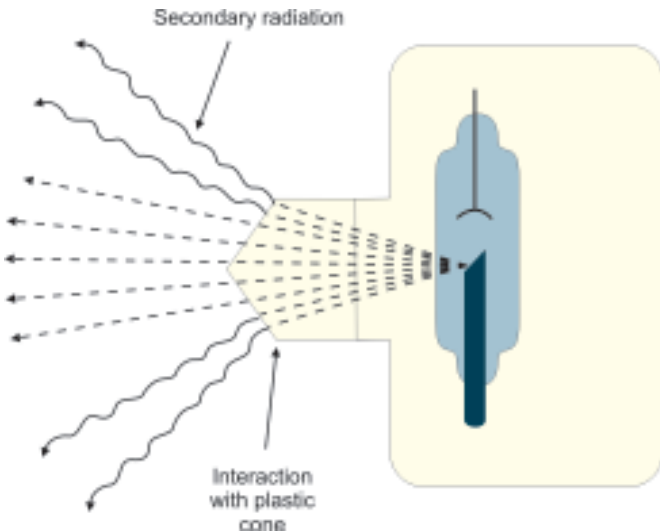


Fig. 6.4: Production of secondary radiation resulting from interaction of the primary beam with the closed-end plastic cone

at the end of the PID which will interact with the X-ray beam. Some believe that rectangular or the cylinder open-ended PID is difficult to aim properly. But now all new dental X-ray machines are made with open-ended PIDs, the problem of closed ended PIDs will eventually disappear. The radiation protection also advice for open ended, lead lined PIDs.

X-RAY BEAM QUALITY AND QUANTITY

X-ray Beam Quality and Voltage

Wavelength determines the energy and penetrating power of radiation. The quality or penetrating power of the X-ray beam is controlled by the kilovoltage. X-rays with shorter wavelengths have more penetrating power, whereas those with longer wavelengths are less penetrating and more likely to be absorbed by matter. In dental radiography, the term quality is used to describe the mean energy or penetrating ability of the X-ray beam. The quality, or wavelength and energy of the X-ray beam, is controlled by kilovoltage.

Kilovoltage and Kilovolt (kV)

Voltage is a measurement of force that refers to the potential difference between two electrical charges. Inside the dental X-ray tube head, voltage is the measurement of electrical force that cause electrons to move from the negative cathode to the positive anode. Voltage determines the speed of electrons that travel from cathode to anode. When voltage is increased, the speed of the electrons is increased. When the speed of the electrons is increased, the electrons strike the target with greater force and energy, resulting in a penetrating X-ray beam with a short wavelength.

Voltage is measured in volts or kilovolts. The volt (V) is the unit of measurement used to describe the potential that drives an electrical current through a circuit.

Dental radiography requires the use of 65 to 100 kV. The use of less than 65 kV does not allow adequate penetration, whereas the use of more than 100 kV results in over penetration. As a rule, the kilovoltage in a dental office remains fixed at one setting for all intraoral radiography.

A kilovoltage range is chosen by the dentist that will indicate the difference of penetration and absorption so that the differences in structural densities can be recorded.

Differential absorption of the X-ray beam by the object being radiographed produces the image. Thus the less dense structures, such as the dental pulp, will appear radiolucent (black) and highly calcified denser structures, such as the enamel, will appear radiopaque (white or gray). The less dense areas in the object allow greater passage of the X-rays than do denser areas, and more X-rays strike the film in these areas to darken it.

Half-value Layer

To describe beam quality and penetration the term half value layer (HVL) is more appropriate than kilovoltage. HVL represents the quality (penetration) of the X-rays emitted from the tube while the kilovoltage is a description of the electric energy put into an X-ray tube. The HVL is defined as the thickness of aluminum (in mm) that will reduce the intensity of the X-ray beam by 50%. For example, a dental X-ray beam could be described as having an HVL of 2 mm. This means that the energy of this particular beam is such that a thickness of 2 mm of aluminum is necessary to decrease its intensity by half (50%). The normal HVL for a dental X-ray beam is about 2.75 mm of aluminum.

Quantity

As the kilovoltage determines the quality (penetrating power) of the X-rays produced, the milliampere determines the quantity (amount) of X-rays produced.

Kilovoltage peak (kVp) can be defined as the maximum or peak voltage. The voltage meter on the control panel measures the X-ray tube voltage, which is actually the peak voltage of an alternating current (AC).

Quantity refers to the number of X-rays produced. Amperage determine the amount of electrons passing through the cathode filament. An increase in the number of electrons available to travel from the cathode to the anode results in production of an increased number of X-rays. The quantity of the X-rays produced is controlled by milliamperage.

MILLIAMPERES (mA)

The ampere (A) is the unit of measure used to describe the number of electrons or current flowing through the cathode filament. One milliampere (mA) is equal to 1/1000 of an ampere. In dental radiography the use of 7 to 15 mA is required; a setting above 15 mA is not recommended because of the excessive heat production in the X-ray tube results.

Milliamperage regulates the temperature of the cathode filament. A higher milliampere setting increases the temperature of the cathode filament and consequently increase the number of electrons produced. A rotating anode is required as they are struck by electrons through only part of their - 360 degree rotation.

It is better to consider milliamperage seconds (mAs) than milliamperage alone.

MILLIAMPERE-SECONDS (mAs)

A combination of milliamperes and exposure time is termed milliamperage-seconds (mAs).

**Milliamperes × exposure time (seconds) =
milliampere – seconds**

When milliamperage is increased; the exposure time must be decreased and vice versa if the density of the exposed radiograph is to remain the same. An exposure at a given kVp of 1 second using 10 mA is 10 mAs.

The sensitivity of the film and focal film distance (FFD) used determine the milliampere seconds required at a given kilovoltage. The more sensitive the film to radiation, the fewer milliampere seconds required. A shorter exposure time is required for a higher milliamperage.

X-RAY BEAM INTENSITY

Quality and quantity are described together in a concept known as intensity. Intensity is defined as the product of the quantity (number of X-ray photons) and quality (energy of each photon) per unit of area per unit of time of exposure.

$$\text{Intensity} = \frac{(\text{no. of photons}) \text{ or } \text{kVp} \times (\text{energy of each photon}) \text{ or } \text{mA}}{\text{area} \times \text{exposure rate}}$$

Intensity of the X-ray beam is affected by a number of factors, including kilovoltage peak, milliamperage, exposure time and distance.

Inverse Square Law

The Inverse Square Law is stated as follows:

The intensity of radiation is inversely proportional to the square of the distance from the source of radiation.

“Inversely proportional” means that as one variable increases, the other decreases. When the source-to-film distance is increased, the intensity of the beam is decreased.

According to the Inverse Square Law, the resultant beam is one fourth intense.

The following mathematical formula is used to calculate the Inverse Square Law:

$$\frac{\text{Original intensity}}{\text{New intensity}} = \frac{\text{New distance}^2}{\text{Original distance}^2}$$

Chapter 7

Film Mounting

The mounting of processed dental radiograph is essential for the interpretation of radiograph. It is easier to view and diagnose radiograph when the radiographs are mounted in their proper anatomic orientation. Properly mounted radiographs make charting and examination in a more orderly procedure.

A thorough knowledge of the normal anatomy of the maxilla, mandible and associated structures is required for radiographers to mount dental radiographs properly. Mounted radiographs can be viewed more efficiently than viewing every single film and are easier to interpret.

The film mounting is the placement of radiograph in correct anatomic order.

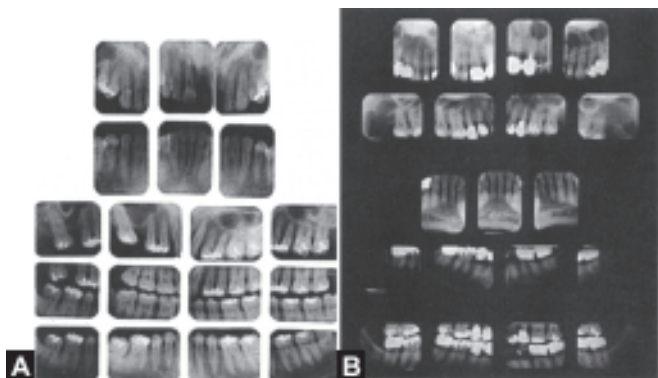
Film mounts are made of cardboard or a celluloid-like material. Various types of dental film mounts are available. Both pedodontic and adult mounts are made. Each film mount has a number of windows or frames in which the individual radiographs are placed or mounted. The area around the film windows may be clear or opaque. The opaque mounts are preferred because its masks the light around each radiograph and viewing is easier and more diagnostic. If the number of radiographs taken does not fill the mounts, the unused windows should be covered to prevent the light from distracting the viewer. The black film paper from the periapical film packet is ideal for placing in the unused frames. Film mounts are available in different sizes and configurations. Film mounts accommodate any number of films. Mounts are available for single films, bitewings, a complete mouth radiographs and endless other combinations of films. The size and shape of the mount are made to fit the various types of view boxes. The dental radiograph should always mount films immediately after processing of film. The operator must always work on a clean, dry light colored table top so that he or she can see the radiographs easily when

they are laid out. The radiographs are viewed on an illuminator or view box placed on or in front of the surface. Film should be mounted in an area designed for film mounting (Figs 7.1A and B).

A special marking pencil is used to write or label on the film mount. The patient's name, chart number, date and number of films taken must be recorded on each mount.

Use of Film Mount

1. It is easy to view and interpret mounted radiographs.
2. Patient record can be easily stored and readily available for interpretation.
3. The chances of error become less because each film is mounted in anatomic order.
4. The touching of the film is prevented which damage the film emulsion.
5. Film mounts mask illumination adjacent to individual radiographs.



Figs 7.1A and B: Full mouth mounting in clear cellulose (A) and opaque mount (B)

Methods of Mounting

The radiographs are viewed on an illuminator or view box placed on or in front of the surface where the mounting is being done.

Two methods are used to mount the films. These methods used the identification by the embossed dot found on the film. The identification dot is a raised bump present on one corner of each internal film packet.

The film packet is placed on the patient's mouth so that the side with the dot is always nearest to the occlusal or incisal surfaces of the teeth.

The film packet is positioned so that the raised dot faces the X-ray beam during exposure. After processing the film should be placed in the film mount so that all the embossed dots are either raised (labial mounting) or depressed (lingual mounting) (Fig. 7.2).

If you mount the radiographs so that the raised portion of the dot is toward you, you are looking at the film as if you

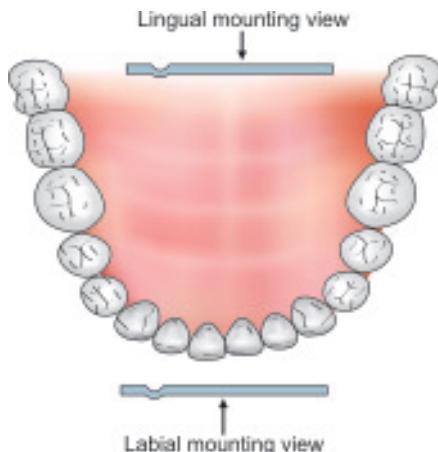
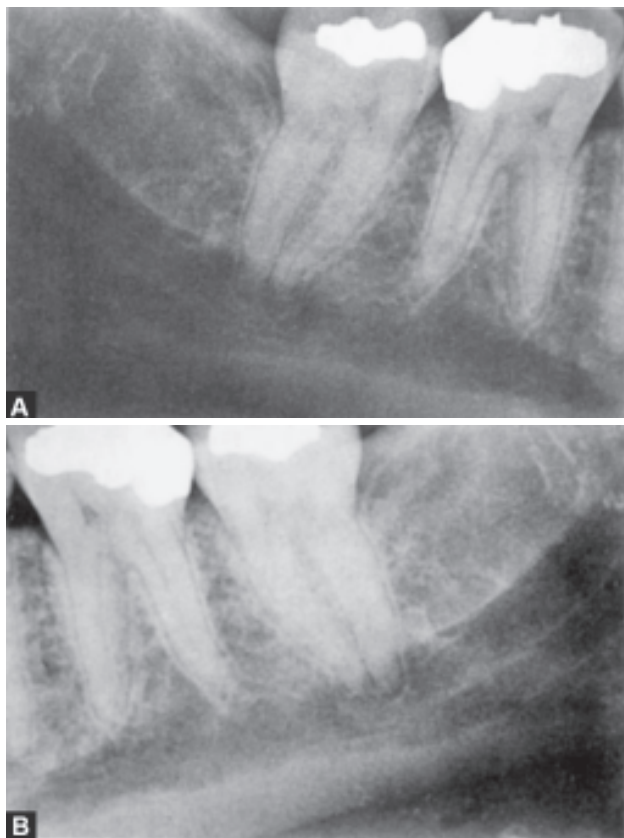


Fig. 7.2: Raised dot on X-ray film and its orientation in film mounts for labial or lingual viewing

were facing the patient, the patient's left side is on your right. This is called labial mounting. In this method, the radiographs are viewed as if the dental radiographer is inside the patient's mouth and looking out. Both mounting systems are used in dentistry but all recommends labial mounting for use in dental offices (Figs 7.3A and B).



Figs 7.3A and B: Radiographs of labial mounting (A) and lingual mounting (B)

Procedure of Mounting

- The films from the patient's full-mouth series are laid out on a clean, dry table top and the empty mount is placed on the view box.
- The patients name, identification number and date of the films are entered on the mount.
- Identify the embossed dot and the films are placed so that the dots are all one way facing up from the operator (labial mounting).
- The films are divided into three groups—bitewings, anterior periapical, and posterior periapical. Bitewings films are identified because the crowns of both the upper and the lower teeth are seen. The anterior periapical films can be identified from the posterior periapical films because of the orientation of the film. In anterior periapical films the long axis of the film is oriented vertically and in posterior periapical films the long axis is oriented horizontally.
- Arrange the radiographs on the work surface according to the anatomic order. The normal anatomic landmarks can be used to distinguish maxillary film from mandibular films. Maxillary teeth are oriented in the mouth with their roots facing up and the mandibular teeth with their roots facing down. Differentiate the maxillary anterior films from the mandibular anterior films on the basis of root and crown shape and anatomic landmarks, such as nasal cavity and maxillary antrum in maxillary films and inferior alveolar canal, mental foramen in mandibular films.

The following criteria are used in mounting films:

1. Maxillary anterior central and lateral incisors have wider crowns and longer roots than mandibular central and lateral incisors.

2. Maxillary premolars (usually first) have two roots, while the mandibular premolars have one root.
3. Maxillary molars have three roots, two buccal and one palatal. The palatal root is the largest and present in between two buccal roots. The mandibular molars have two divergent roots, one mesial and one distal.
4. Mostly the roots curve distally in both maxillary and mandibular arches.
5. The curve of spee is present in mandibular teeth which is concave and the maxillary arch has convex curvature as it goes distally.
 - The order of teeth can be used to distinguish the right and left.
 - Bitewing films can be mounted by orienting the curve of spee for placement.
 - Place each film in the corresponding frame of the film mount and secure it.

The order is:

1. Maxillary anterior (periapical films)
2. Mandibular anterior (periapical films)
3. Bitewings
4. Maxillary posterior (periapical films)
5. Mandibular posterior (periapical films)

Then again check the radiographs by verifying that:

- (a) The film mount is properly labeled and dated.
- (b) All raised dots are oriented correctly.
- (c) All films are arranged in normal anatomic order.
- (d) All films are mounted securely.

Film Viewing

Film viewing is the examination and interpretation of dental radiographs. Dental surgeons should be trained enough with a knowledge of the normal anatomic landmarks of the

maxilla, mandible and related structures to view dental radiographs.

Two equipments are required for film viewing, a view box and a magnifying glass.

A view box of appropriate size is required to view dental radiographs accurately and assist in the interpretation of images. The viewing area of the box should be large enough to accommodate a variety of mounted film. This is also used for viewing panoramic, extraoral films. The light of the view box should be of uniform intensity and evenly diffused.

Pocket sized magnifying glass is used for better interpretation of film details. Magnification helps to view slight changes in density and contrast in radiographic images.

The radiographs can be viewed in a view box in a room with dimmed lighting.

Mounted radiographs must be viewed in segmental order to prevent errors in interpretation.

The sequence in which the film can be viewed is as follows:

1. Dental caries and size and shape of the pulp chamber and canals.
2. Unerupted impacted and missing teeth.
3. Calculus, bony changes and bone resorption.
4. Shape and curvature in the root.
5. Periapical areas.
6. Any pathology, fracture, condition of sinuses, etc.

Record all radiographic findings in the patient record.

Chapter 8

Infection Control in Dental Radiography

Infection control in the practice of dentistry has become a major concern due to increased risk to the patients' health care workers for acquiring tuberculosis, acquired immunodeficiency syndrome (AIDS), the highly infectious hepatitis B and C viruses (HBV and HCV). After the emergence and identification of AIDS in 1981, rigorous hygienic procedures were introduced in dental practice. The primary goal of infection control procedures is to prevent cross contamination between patients and between patients and health care workers.

The infection control policy in dentistry must include protocols for radiology, which includes chair side technique and darkroom procedures. Radiology is not exempt from infection control. Infectious disease can be transmitted by the cross contamination of equipment, supplies, film packets and cassettes used to take radiographs. An operator's hands may become contaminated by contact with a patient's mouth and saliva mix with infected blood, contaminate films and film holders. Cross contamination may also occur when operators open film packets to process the films in the darkroom. If we understand and practice infection control, we can protect our patients, our fellow workers and ourselves from harm. We, as dental professionals, should act in a manner befitting our profession. The protection can be done by wearing gloves when contact with blood, saliva or other infectious material, items or surfaces is anticipated. Masks, eyeglasses and aprons with full sleeves are required when splatter of blood or saliva is anticipated.

Patient history is important before any dental procedures to identify infectious diseases. The dental professional should obtain a current medical history at the initial or recall visit using a questionnaire. Information gained by the history will alert the dental team to the presence of infectious disease.

But the rational should be to treat every patient with universal precautionary procedures carried out at all times.

Sources of Infection

The main sources of pathogen transmission is by contact with saliva, blood, secretions (nasal and respiratory) present in the oral cavity. After the contamination by oral fluids during radiographic procedures, everything that person touches with his gloves is a possible transmitter of pathogens, film holding devices, film, X-ray machine, tube head, light handle, control panel and exposure switch, dental chair, processors, etc.

Any object can be contaminated that the operator touches after placing the packet in the patient's mouth and a source of transmission of infection. Thus protection and precautions must be used to prevent transmission of infective microorganisms. These precautions are wearing of gloves, masks, protective eyeglasses, aprons and plastic coverings.

Precautions Taken to Prevent Cross Contamination

Dental Professionals

Dental professionals always wear gloves, masks, eyeglasses and aprons when making radiographs or handling contaminated film packets.

Blood is the most common and easy route of transmission of HIV, HBV and HCV. Although saliva is not considered to be a risk for HIV transmission but because saliva is often contaminated with blood, there is a potential for transmission. After seating the patient, wash hands with antiseptic soap and put on gloves.

Face masks and protective eyeglasses should be worn by dental professionals whenever they perform any

intraoral radiographic procedure. Masks and eyeglasses should not be removed till the completion of processing of film.

Barriers

Any object, such as chair, X-ray machine, that the operator touches after placing the film in the patient's mouth must be covered with a removable barrier. Plastic bags, plastic wraps and aluminum foil are good barriers for covering over the chair head rest, the counter top, the arm and PID (cone) of the X-ray machine, control panel and exposure button. These barriers can be easily removed after the radiographic procedure is completed. These objects can also be disinfected if barriers are not used. But these disinfecting solutions may affect corrosion of X-ray machine and electrical connections in the head of the machine. Good surface disinfectants are iodophors, chlorines and synthetic phenolic compounds. It is better to use barriers to cover working surfaces that were previously cleaned. Barriers protect the underlying surface from becoming contaminated.

The dental chair head rest, head rest adjustments and chair back may be easily covered with a plastic bag. Also cover the X-ray tube head, PID, exposure switch and exposure time control. Secure the bag by tying a knot in the open end or by placing a rubber band over the X-ray tube head.

Panoramic and cephalometric are extraoral procedure, thus fewer areas are contaminated by the patient's saliva. The equipment in these X-ray units should be decontaminated and disinfected as other equipment. The patient bite block should be covered by a plastic barrier cover or autoclaved if possible. Plastic barrier wrap should be used on the chin rest, ear rods and patient handgrips. Processing presents no problems because the cassette does not contact the patient.

The contaminated glove used on patient should be removed before the cassette is taken for the processing from the panoramic unit.

FILM PACKETS

The film packet is the main source of cross contamination. The film packet is placed in the patient's mouth and when removed it is coated with saliva and sometimes with blood. This film packet is then transported to the darkroom.

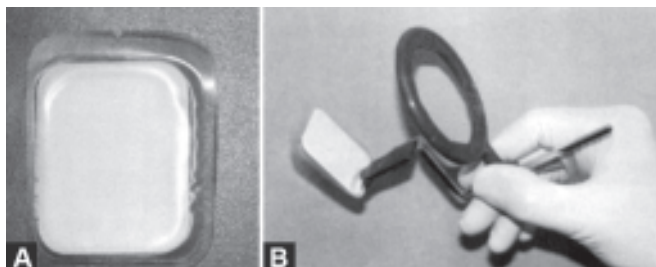
To prevent the transmission of pathogen by the film packet the following precautions should be taken:

1. Sterilization or disinfection of the exposed packets.
2. Use of barrier protection for the packet.
3. Proper handling of the film packet.

Neither the sterilization nor disinfection of the film packet is recommended because these processes are time consuming and damage the film. Autoclaving or dry heat sterilization destroys the image. Immersion of the film packet into the disinfection solution results in penetration of the solution to the film emulsion.

Some of the companies are now marketing a barrier envelop for the film packets. The Kodak company provides D and F speed film (sizes 0, 1 and 2) in which the film packet is inserted into barrier envelop. The separate barrier envelopes are also available in which the individual film packet may be inserted.

During the radiographic procedure the film packet is placed and sealed in the barrier envelope (Figs 8.1A and B). The film packet is exposed in the barrier envelope, dried of saliva and then brought to the darkroom. The operator wears gloves to open the barrier envelope, the film packet should not be touched and then the packet is allowed to drop into a disposable glass. The gloves and barrier envelope are then discard and the operator opens the film and process the film by his bare hands or by wearing another gloves.



Figs 8.1A and B: (A) Film packet barrier, (B) Film holder barrier

If the film packet barrier is not used, the contaminated film packet after the exposure should be wiped dry, carried to the darkroom without touching anything on the way to the darkroom. The operator can change the gloves after the exposure have been made if touching surfaces and objects are unavoidable. Under the safelight conditions, the operator can open the film packet, without touching the film inside the packet, then the film is dropped on a clean surface. The contaminated gloves are discarded and the films are processed either manually or automatically.

Processing Solutions

The contaminated film when processed remains contaminated because the developing and fixing solutions are not the sterilizing agent. The microorganism becomes viable for 48 hours on contaminated radiographic equipment. The contaminated film also contaminates the rollers and tracts in the automatic processors.

Precautions

On Chair Side Exposure Procedures

1. Sterilize and disinfect all the exposed surfaces with the disinfectant solutions.

2. Cover all the surfaces such as X-ray machine, the control panel, the PID, the exposure button with the plastic wrap (Figs 8.2A and B).



Figs 8.2A and B: (A) Plastic wrap covering PID, (B) Plastic wrap covering exposure button

3. Plan all the anticipated suppliers (film, film holder, cotton rolls, etc.) and setting out.
4. Drape the patient with lead apron and seat on the chair.
5. Operator wash his hands with antiseptic solution and wear the gloves.
6. Put the film in the patient's mouth, make the exposure only touching the covered surfaces.
7. Remove the exposed film from the mouth, wiped dry of saliva, put the film in a disposable cup.
8. Dispose off all contaminated covering on the surfaces.
9. Remove the contaminated gloves and carry the film container to the darkroom for processing.

Processing Procedures in Darkroom

1. Wear new gloves.
2. Remove the film from the film packet in the safe light with gloved hands and drop the film onto a clean container. Do not touch the film with the contaminated gloves because they touched the film packet.
3. Dispose the gloves and the film packet.
4. Uncontaminated film is processed either manually or automatically.
5. Gloves are not required because the film is not contaminated.

Precautions in Automatic Processing

The operator should take same precautions in automatic processing as in manual processing procedure to avoid cross contamination. The problem in automatic processors is the use of daylight loaders. Use of daylight loaders should be avoided because it is difficult to prevent contamination as a result of light fitting hand buffles, which results in cross contamination. To prevent this one can use the barrier packs.

By using this barrier packs the film is removed from the film packet and put on his gloves within the confined space of the daylight loader and then take off the contaminated gloves and feed the film into the up take slots.

Precautions Taken in the Panoramic X-ray Units

1. Patient bite block should be covered by a plastic barrier cover.
2. Chin rest, ear roads and the patient handgrips should be wrapped by the plastic barrier.
3. The gloves should be removed before the cassette is taken from the panoramic X-ray unit because the film is not contaminated from the patient's contact.
4. Film can be processed without any problem of contamination.

Chapter 9

Characteristics of Radiographic Film

The characteristics of radiographic film depend on the following features of the film.

Optical Density

Density is the degree of silver balancing by the deposits of black silver particles in darker areas. If the density of a film is too great, the film appears too dark, resulting into images that cannot be visually separated from each other.

$$OD = \log \frac{\text{Incident light intensity}}{\text{Transmitted intensity}}$$

Optical density is the term used for describing the degree of film blackening and can be measured directly using a densitometer. In diagnostic radiology the range of optical densities is usually 0.25-2.5. There are no units for optical density.

Film Speed

This is the exposure required to produce an optical density of 1.0 above background fog. Thus, the faster the film the less the exposure required for a given film blackening and the lower the radiation dose to the patient. Film speed is a function of the number and size of the silver halide crystals in the emulsion. The larger the crystals the faster the film but the poorer the image quality.

Nowadays, the faster films consistent with adequate diagnostic results should be used such as D, E or F speed (Table 9.1).

TABLE 9.1: Intraoral film speed classification

<i>Film speed group</i>	<i>Speed range (reciprocal roentgens)</i>
C	6 - 12
D	12 - 24
E	24 - 48
F	48 - 96

Reciprocal roentgens are the reciprocal of the exposure in roentgens required to obtain a film with an optical density of 1.0.

Film Sensitivity

This is the reciprocal of the exposure required to produce an optical density of 1.0 above background fog. A fast film has a high frequency.

Background fog density is the small degree of blackening, evident even with zero exposure. This is due to the color/density of the plastic base or the development of some unexposed silver halide crystals.

If the film has been stored correctly, this background fog density should be less than 0.2.

Film Latitude

This is a measure of range of exposures that produces distinguishable differences in optical density, i.e. the linear portion of the characteristic curve. This is a graph showing the variation in optical density (degree of blackening) with different exposures.

Film Contrast

This is the difference in optical density between two points on a film that have received different exposures. A dental radiograph that has very dark and very light areas is said to have high contrast. A radiograph that has many shades of gray and does not have very dark and very light areas is said to have low contrast. In dental radiography the term scale of contrast is used for the range of useful densities seen on a dental radiograph.

Film Gamma

This is the maximum gradient or slope of the linear portion of the characteristic curve.

Average Gradient

This is the most useful measurement and is usually calculated between density 0.25 and 2.0 above background fog.

The film gamma or average gradient measurement determines both film latitude and film contrast.

- If the gamma or average gradient is high, the film will show good contrast, but will have less latitude.
- If the gamma or average gradient is low, the film will show poor contrast, but will have wider latitude.

Resolution (Resolving Power)

This is a measure of the radiographs ability to differentiate between different structures that are close together. Factors that can affect resolution include Penumbra effect (image sharpness), silver halide crystal size and contrast. It is measured in line pairs (lp) per millimeter (mm). Direct action film has a resolution of approximately 10 lp/mm and indirect action film has a resolution of about 5 lp/mm.

Chapter 10

Film Processing

To produce high-quality diagnostic dental radiographs, dental X-ray film must be properly exposed and processed. Film processing procedures directly affect the quality of dental radiograph.

FILM PROCESSING

The purpose of film processing is two fold:

- To convert the latent (invisible) image on the film into a visible image.
- To preserve the visible image so that it is permanent and does not disappear from the dental radiograph.

LATENT IMAGE FORMATION

Silver halide crystals absorb X-radiation during X-ray exposure and store the energy from the radiation; depending on the density of the objects in the area exposed, silver halide crystals contain various crystals on the film that are positioned behind an amalgam filling receive almost no radiation. The amalgam filling is dense and absorbs the X-ray energy. As a result, the silver halide crystals are not energized. In contrast, the silver halide crystals that correspond to airspace (no density) receive more radiation and are highly energized.

The stored energy within the silver halide crystals forms a pattern and creates an invisible image within the emulsion on the exposed film. This pattern of stored energy on the exposed film cannot be seen and is referred to as a latent image. The latent image remains invisible within the emulsion until it undergoes chemical processing procedures. When the exposed film with latent image is processed, a visible image results.

From Latent Image to Visible Image

A chemical reaction takes place when a film with a latent image is immersed in a series of special chemical solutions. During processing, a chemical reaction occurs, and the halide portion of the exposed, energized silver halide crystal is removed; chemically, this is referred to as a reduction. Reduction of the exposed silver halide crystals results in precipitated black metallic silver.

During film processing, selective reduction of exposed silver halide crystals occurs. Selective reduction refers to the reduction of the energized, exposed silver halide crystals into black metallic silver while the unenergized unexposed silver halide crystals are removed to the film. The latent image is made visible through processing procedures and can be described as follows:

1. The film is placed in a chemical known as the developer solution for a specific amount of time and at specific temperature. The developer initiates a chemical reaction that reduces the exposed silver halide crystals into black metallic silver and creates dark or black areas on a dental radiograph. At the same time, the unexposed silver halide crystals remain virtually unaffected by the developer.
2. Following the development process, the film is rinsed in water to remove any remaining developer solution.
3. Next, the film is placed in a special chemical known as the fixer solution for a specific amount of time. The fixer solution removes the unexposed silver halide crystals and creates white or clear areas on the dental radiograph. Meanwhile, the black metallic silver is not removed and remains on the film. Following the fixing process, the film is washed in water to remove any remaining traces of the chemical solutions and then dried (Fig. 10.1).

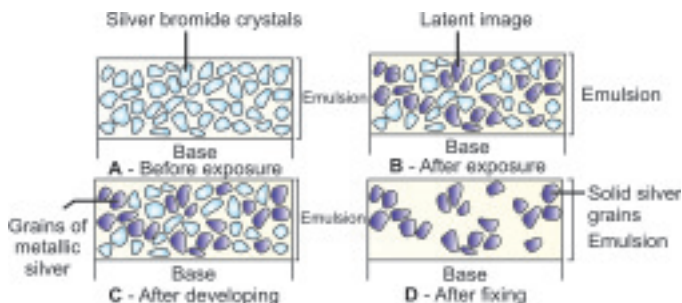


Fig. 10.1: Changes in emulsion during film processing

VISIBLE IMAGE

The visible image that results on a dental radiograph is made up of black, white and gray areas. The black areas seen on a dental radiograph are created by deposits of black metallic silver. The amount of deposited black metallic silver seen on a dental radiograph varies depending on the structures being radiographed.

Radiolucent

A radiolucent structure is one that readily permits the passage of the X-ray beam and allows more X-rays to reach the film. If more X-rays reach the film, more halide crystals in the film emulsion are exposed and energized, thus resulting in increased deposits of black metallic silver. A radiograph with large deposits of black metallic silver appears black, or radiolucent.

Radiopaque

A radiopaque structure is one that resists the passage of the X-ray beam and restricts or limits the amount of X-rays that reach the film. If no X-rays reach the film, no silver halide

crystals in the film emulsion are exposed, and no deposits of black metallic silver are seen. A radiograph with areas of unexposed silver halide crystals that have been removed during processing and no black metallic silver deposits, appears white or radiopaque.

FILM PROCESSING STEPS

There are five steps in film processing:

1. Immersion of exposed film into developer solution.
2. Rinsing with water.
3. Immersion in fixing solution.
4. Washing.
5. Drying and mounting.

Developing Stage

The first step in film processing is development. A chemical solution known as the developer is used in the development process. The purpose of the developer is to chemically reduce the exposed, energized silver halide crystals into black metallic silver. The developer solution softens the film emulsion during this process.

Time-Temperature versus Sight Development

The correct way to process dental X-ray film is by time-temperature development. This scientific method produces optimum information on the film. Most of the dental surgeon prefer development by sight. The technique is to immerse the film in the developer, remove it at frequent intervals, hold it in the safe light until root shapes or fillings are visible. At that point the film are washed and placed in the fixer. But this is an unacceptable method. Sight development is unfair to the patient because it does not provide the maximum diaphoretic information. The time-temperature method is the only acceptable to process dental X-ray films (Table 10.1).

TABLE 10.1: Developing time according to temperature variation

<i>Temperature</i>	<i>Developing time</i>
65° F	6 minutes
68° F	5 minutes
70° F	4.5 minutes
72° F	4 minutes
76° F	3 minutes
80° F	2.5 minutes

Rinsing

Following development of film, water bath is used to wash or rinse the film. Rinsing is necessary to remove the developer from the film and stop the development process.

Fixation

Following rinsing, fixation takes place. A chemical solution known as the fixer is used in the fixing process. The purpose of the fixer is to remove the unexposed, unenergized silver halide crystals from the film emulsion. The fixer hardens the film emulsion during this process. Fixation time is 10-15 minutes, double the developing time.

Washing

Following fixation, a water bath is used to wash the film. A washing step is necessary to thoroughly remove all excess chemicals from the emulsion. Washing is done for 20 minutes in running water.

Drying

The final step in film processing is the drying of the films. Films may be air-dried at room temperature in a dust-free

area or placed in a heated drying cabinet. The film is dried by circulating warm air.

RAPID PROCESSING

Rapid processing (hot processing) of dental radiographs is done with the use of higher solution temperatures, concentrated solutions, agitating of the film or a combination of these. It is called hot processing because of higher temperature of the solutions. Rapid processing does not require an increase in radiation to the patient, but the images produced are not well defined as by standard methods. The use of rapid processing is required when time is more important than the exact detail of the image.

Rapid processing can be achieved by the use of regular strength developing solutions at 92 °F with agitation of the film which produces an acceptable diagnostic image in less than a minute (20 seconds developing, 3 seconds washing and 30 seconds fixing). The concentrated solution produces increased chemical activity which makes the processing rapid. Rapid processing is used in endodontic work and in postoperative requirement of radiography in oral surgery.

FILM PROCESSING SOLUTIONS

Film processing solutions may be obtained in the following forms:

- Powder
- Ready-to-use liquid
- Liquid concentrate

Two chemical solutions are necessary for film processing:

- Developer
- Fixer

DEVELOPER SOLUTION

The developer solution contains the following four basic ingredients:

Developing Agent

The developing agent (also known as the reducing agent) contains two chemicals—hydroquinone (paradihydroxybenzene) and Elon (monomethy-para-aminophenol sulfate). The purpose of the developing agent is to reduce the exposed silver halide crystals chemically to black metallic silver. Hydroquinone generates the black tones and the sharp contrast of the radiographic image. Hydroquinone is temperature sensitive; it is inactive below 60 °F and very active above 80 °F. Because this chemical is sensitive to temperature, the temperature of the developing solution is critical. The optimal temperature for the developer solution is 68 °F. Elon, also known as metol, acts quickly to produce a visible radiographic image. Elon generates the many shades of gray seen on a dental radiograph. This chemical is not temperature sensitive. If hydroquinone and Elon were used individually instead of in combination, Elon would produce a film that appeared gray with indistinct contrast, whereas hydroquinone would produce a film that appeared black and white. By using a combination of these chemicals, a film with black, white and shades of gray is produced. Hence these chemicals bring contrast of image.

Preservative

The antioxidant sodium sulfate is the preservative used in the developer solution. The purpose of the preservative is to prevent the developer solution from oxidizing in the presence of air. The reducing agents hydroquinone and Elon are not stable in the presence of oxygen and readily absorb oxygen

from the air. If these agents react with oxygen the action of the developer solution is weakened. The preservative helps to prevent this weakening and to extend the useful life of hydroquinone and Elon.

Accelerator

The alkali sodium carbonate is used in the developer solution as an accelerator. The purpose of the accelerator (also called the activator) is to activate the developing agents. The developing agents are active only in an alkaline (high pH > 11) environment. For example, hydroquinone and Elon do not develop when used alone; the presence of an alkaline accelerator is required. The accelerator not only provides the necessary alkaline environment for the developing agents but also softens the gelatin of the film emulsion so that the developing agents can reach the silver halide crystals more effectively. The other activator which can be used as accelerator are sodium hydroxide, sodium metaborate, sodium tetraborate.

Restrainer

The restrainer used in the developing solutions is potassium bromide. The purpose of the restrainer is to control the developer and to prevent developing the exposed and unexposed silver halide crystals. Although the restrainer stops the development of both exposed and unexposed crystals, it is most effective in stopping development of the unexposed crystals. Thus the restrainer prevents the radiographic image from appearing fogged; a fogged film appears dull gray, lacks contrast, and is nondiagnostic.

FIXER SOLUTION

The fixer solution contains the following four basic ingredients:

Fixing Agent

The fixing agent (also known as the clearing agent) is made up of sodium thiosulfate or ammonium thiosulfate and is commonly called "hypo". The purpose of the fixing agent is to remove or clear all unexposed and undeveloped silver halide crystals from the film emulsion. This chemical clears the film so that the Black image produced by the developer becomes readily distinguished.

Preservative

The same preservative used in the developer solution, sodium sulfite, is also used in the fixer solution. The purpose of the preservative is to prevent the chemical deterioration of the fixing agent.

Hardening Agent

The hardening agent used in the fixer solution is potassium alum. The purpose of the hardening agent, as the name suggests is to harden and shrink the gelatin in the film emulsion after it has been softened by the accelerator in the developer solution.

Acidifier

The acidifier used in the fixer solution is acetic acid or sulfuric acid. The purpose of the acidifier is to neutralize the alkaline developer. Any unneutralized alkali may cause the unexposed crystals to continue to develop in the fixer. The acidifier also produces the necessary acidic environment required for the fixing agent.

REPLENISHING

The solutions of developer and fixer should be replenished daily. Approximately each day for the developer and fixer

solutions. Commercially prepared replenishment solutions are available. Commercial replenishers include manufacturer's instructions. The replenisher is added to the existing solutions in their respective tanks to bring them to the proper fluid levels. The solutions should be kept at the top of the tank so that the film should be immersed completely into the solution. Water should not be added to the solution because this dilutes the strength of the chemicals.

DARKROOM SPECIFICATIONS

The primary function of a darkroom is to provide a completely darkened environment where X-ray film can be handled and processed to produce diagnostic radiographs. The darkroom must be properly designed and well equipped.

Room Requirements

A well-planned darkroom makes processing easier. The ideal darkroom is the result of careful planning; it must be

- conveniently located.
- of adequate size.
- equipped with ample work space with adequate storage.
- temperature and humidity controlled.

Location and Size

The location of the darkroom must be convenient; ideally, it should be located near the area where X-ray units are installed. The darkroom must be large enough to accommodate film processing equipment and to allow ample working space. A darkroom should measure at least 16 to 20 square feet and provide enough space for one person to work comfortably. The size of the darkroom is determined by a number of factors:

1. The volume of radiographs to be processed.
2. The number of dental professional handling the processing.
3. The type of processing to be done (Manual or automatic).
4. The space required for duplicating, drying and storage.

Lighting

As the term darkroom suggests, this room must be completely dark and must exclude all visible white light. The term light-tight is often used to describe the darkroom. To be considered light-tight, no light leaks can be present. Any white light that "leaks" into the Darkroom (e.g. from around a door or through a vent) is termed a light leak. In a darkroom, when all the lights are turned off and the door is closed, no white light should be seen. Any white light coming around the door, through a vent or keyhole, or through a wall or ceiling seam is a light leak and must be corrected with weather stripping or black tape. The X-ray film is extremely sensitive to visible white light, any leaks of white light in darkroom cause film fog. A fogged film appears dull gray, lacks contrast and is nondiagnostic.

Two types of lighting are essential in a darkroom:

- Room lighting
- Safe lighting

Room Lighting

Incandescent room lighting is required for procedures not associated with the act of processing films. An overhead white light that provides adequate illumination for the size of the room is necessary to perform tasks such as cleaning stocking materials and mixing chemicals.

Safe Lighting

The special kind of lighting that is used to provide illumination in the darkroom is termed safe lighting. It is a low-intensity light composed of long wavelengths in the red-orange portion of the visible light spectrum. Safe lighting provides sufficient illumination in the darkroom to carry out processing activities safely without exposing or damaging the film. Safe lighting does not rapidly affect unwrapped X-ray film and does not cause film fog.

A safe light typically consists of a lamp equipped with a low-wattage bulb (7W or 15 watts) and a light filter (GBX-2 filter). The working in safe light must not to exceed 5 minutes.

Cell Phones

The explosion in the use of cell phones has produced another possible source of light that could fog or completely expose and ruin the film. When the cell phone is opened the instrument produces light that affects the X-ray film. This is more likely to occur in extraoral and panoramic film as they are more sensitive to light because panoramic and extraoral films used with intensifying screens are more prone who are using their cell phones sensitive to light than periapical films.

In the darkroom, the use of cellphone is more likely the possibility of affecting the film. Therefore, the cell phones should not be used in the darkroom during the processing of the film.

Processing Tanks

The tank must have hot and cold running water and a means of maintaining the temperature between 60 °F and 75 °F. The size of the master tank is about 20 × 25 cm (8 × 10 inches) in which two removable inserts can be fitted inside. The insert

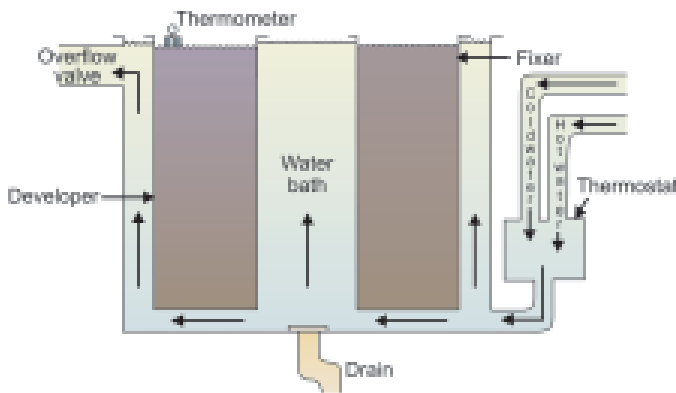


Fig. 10.2: Typical processing tanks in dental office

usually holds 1 gallon (3.8 liter) of developer or fixer. The developer is usually placed on the left side and the fixer on the right side in the insert tank of the master tank. The unit should be made of stainless steel. Each tank is equipped with a lid that should be kept covered on at all times to prevent oxidation and evaporation of the processing solutions (Fig. 10.2).

Thermometer

To monitor the temperature of the master tank a thermometer can be left in the circulating water. Thermometers may contain alcohol or metal but not mercury because they could break and contaminate the solutions.

Timer

An interval time is placed for controlling development and fixation times.

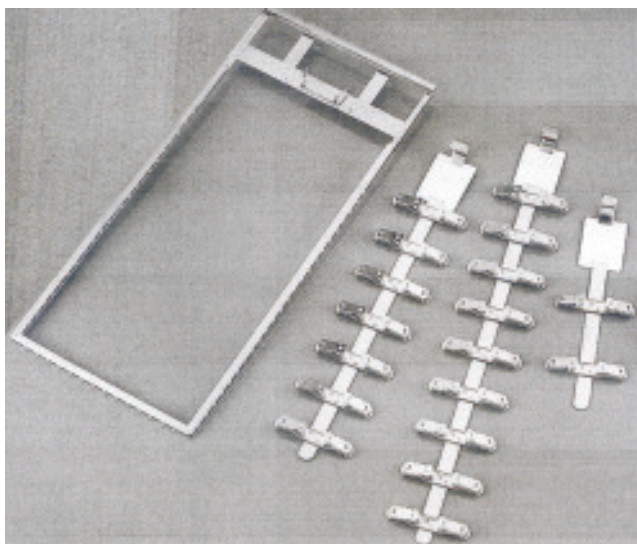


Fig. 10.3: Different sizes of film hangers

Film Hanger

Intraoral film hangers come in various sizes and contain clips for 2 to 20 films (Fig. 10.3). The film should be unwrapped and attached to the clips. The film should not be touched with contaminated gloves. The working surface on the film hanger should be clean and dry to prevent film staining. Film hangers should be numbered or have the patients' name written to them to avoid mix-ups. Hangers with defective clips should be discarded. A film hanger that is defective should be discarded.

Drying Racks

The drying racks can be mounted on the wall for film hangers. An electric fan is used to circulate the air and speed for drying

of the film. Drip trays can be placed underneath the racks to catch water that may run off the wet films.

MANUAL PROCESSING PROCEDURES

The steps for manual processing of film are:

1. Prepare the solution: The first step to prepare (replenish) the developer and fixer for the manual tank. For proper strength of the developer and fixer solution add 8 ounces per gallon of the powder or liquid to fresh water.
2. Stir the developer and fixer solution. This is required to thoroughly mix the chemicals and equalize the temperature of the tanks. Temperature is important for proper developing time.
3. Mounting of the X-ray film on hangers: By using safe light illumination in the darkroom. The exposed film is removed from the packet or cassette. The film is held in the hanger only by their edge to avoid any damage to the film surface.
4. Set the timer for development: By checking the temperature of the developer, set the timer according to the time indicated for the temperature of the solution, e.g. for 76 °F temperature the development time is 3 minutes.
5. Development of the film: Immerse the hanger and film in the developer after starting the timer, the film must be fully dipped into the developer solution. Agitate the hanger mildly for 5 seconds to remove air bubbles over the film. Then leave the film in the developer solution for the predetermined time.
6. Rinse the film in the running water: Place the film after removal from the hanger in the running water for 30 seconds and remove excess developer thus minimising contamination of the fixer.

7. Fix the film in the fixer solution: Place the film in the fixer solution for 10 minutes and agitate for 5 times of every 30 seconds. This will eliminate air bubbles and bring fresh fixer into contact with the film.
8. Washing and drying of the film: Place the film in running water for 10 minutes to remove residual developer and fixer solutions.

Then dry the film in circulating warm air after gently shaking the film to remove excess water from the film surface. Otherwise, it may result into a drying artifact because of clinging of drop of water on the film surface.

AUTOMATIC FILM PROCESSING

Automatic film processing is another simple method that is used to process dental X-ray films. The automatic processor automates all film processing steps. Automatic processing is often preferred over manual film processing for four reasons (Fig. 10.4):

- Less processing time is required.
- Time and temperatures are automatically controlled.

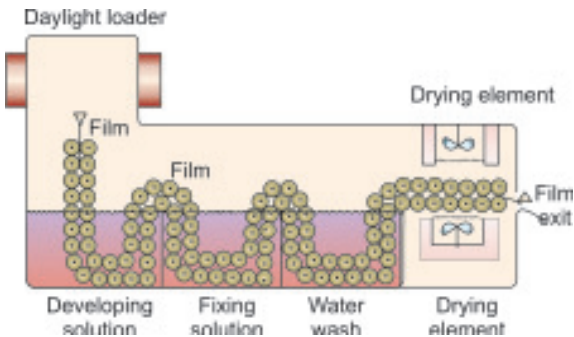


Fig. 10.4: Automatic film processor

- Less equipment is used.
- Less space is required.

An automatic processor requires only 4 to 7 minutes to develop, fix, wash and dry a film, whereas manual film processing techniques require approximately 1 hour. Another advantage is the automatic control of timer and temperature, the automatic processor maintains the correct temperature of solutions and controls the processing time, thus contributing to the uniformity of film processing.

Component Parts of the Automatic Processor

The automatic processor uses a roller transport system to move the unwrapped dental X-ray film through the developer, fixer, water and drying compartments. Each component of the automatic processor contributes to the mechanism of automatic film processing and has a specific function.

The processor housing encases all of the component parts of the automatic processor.

The film feed slot is an opening on the outside of the processor housing that is used to insert unwrapped films into the automatic processor.

The roller film transporter is a system of rollers used to move the film rapidly through the developer, fixer, water and drying compartments. The rollers are propelled by motor-driven gears or belts. In addition to moving the film, the rollers produce a wringing action that removes the excess solution from the emulsion as the film moves from compartment to compartment. The motion of the rollers also gently agitates the processing solutions, contributing to the uniformity of the processing.

The developer compartment holds the developer solution. The developer solution used in an automatic processor is a

specially formulated, highly concentrated chemical solution designed to react at temperatures between 80 °F and 95 °F. As a result of the high temperature, developments occur rapidly.

The fixer compartment holds the fixer solution. The film is transported directly from the developer solution into the fixer without a rinsing step. The fixer solution used in an automatic processor is a specially formulated, highly concentrated chemical solution that contains additional hardening agents. In the fixer solution, the film is rapidly “fixed or cleared” and then hardened.

The water compartment holds circulating water. Water is used to wash the films following fixation. After washing the wet film is transported from the water compartment to a drying chamber.

The drying chamber holds heated air and is used to dry the wet film.

A replenisher pump and replenisher solutions are used to maintain proper solution concentration and levels automatically in some automatic processors, whereas other processors require the operator to add the necessary replenishing solutions.

The film recovery slot is an opening on the outside of the processor housing where the dry processed radiograph emerges from the automatic processor.

Film processing can produce radiographs of excellent quality, poor radiographs contribute to a loss of diagnostic information and loss of time.

PROBLEMS DURING PROCESSING

Problem during processing can occur due to a number of reasons:

- Time and temperature.
- Chemical contamination.



Fig. 10.5: Radiograph of underdeveloped film appears light

- Error in film handling.
- Lightening errors.

Underdeveloped Film

The film appears light (Fig. 10.5).

Problems

Underdeveloped films may result from:

1. Inadequate development time.
2. Inaccurate timer.
3. Low developer temperature.
4. Inaccurate thermometer.
5. Depleted or contaminated developer solution.

Underdeveloped films are prevented:

- Check the temperature of the developer as well as the time the film must remain in the developer solution.
- Increase the time the film remains in the developer as needed.



Fig. 10.6: Radiograph of overdeveloped film appears dark

- Replace faulty and inaccurate thermometers and timers.
- If developer is depleted or contaminated, replace it with fresh developer solution.

OVERDEVELOPED FILM

The film appears dark (Fig. 10.6).

Overdeveloped films may result from:

1. Excess development time.
2. Inaccurate timer.
3. High developer temperature.
4. Inaccurate thermometer.
5. Concentrated (overactive) developer solution.

Overdeveloped films are prevented:

- Check the temperature of the developer and the time the film should remain in the developer solution.
- Decrease the time the film remains in the developer as needed.

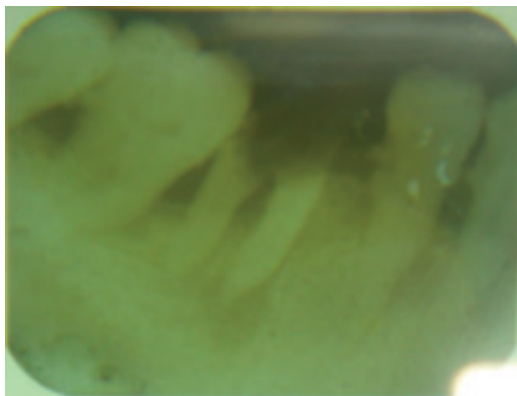


Fig. 10.7: Radiograph showing developer dark spots

CHEMICAL CONTAMINATION

Developer Spots

Developer spots are seen when the developer solution comes in contact with the film before processing. Dark spots appear on the film (Fig. 10.7).

Avoid developer spots to:

- Use a clean work area in the darkroom.
- To ensure a clean working surface place a paper towel on the work area before unwrapping films.

Fixer Spots

Problems

Fixer spots are the result of fixer solution coming in contact with the film before processing. White spots appear on the film (Fig. 10.8).

Avoid fixer spots to:

- Use a clean work area in the darkroom.
- To ensure a clean working surface place a paper towel on the work area before unwrapping films.

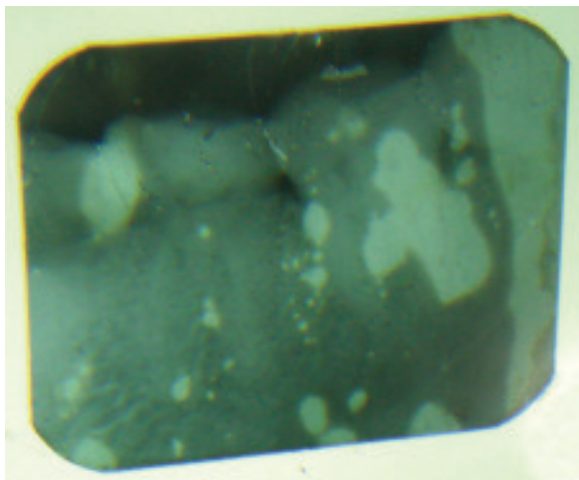


Fig. 10.8: Radiograph showing fixer white spots

YELLOW-BROWN STAINS ON THE FILMS

Problems

Yellow brown films result from:

- Use of exhausted developer or fixer.
- Insufficient fixation time.
- Insufficient rinsing.

To prevent yellow-brown films:

- Replace depleted developer and fixer solutions with fresh chemicals.
- Make certain that films have adequate fixation time and adequate rinse time.
- Rinse processed films for a minimum of 20 minutes in circulating cool water.

OVERLAPPED FILMS

Overlapped films occur when two films come into contact with each other during manual or automatic processing



Fig. 10.9: Overlapped film showing black areas in fixer

techniques. Films that overlap in the developer have white areas that represent an undeveloped portion of the film. Films that overlap in the fixer have black areas that represent an unfixed portion of the film (Fig. 10.9).

Solution

To avoid overlapped films, care should be taken to ensure that no film is permitted to come into contact with another film during processing.

AIR BUBBLES

Air bubbles are seen when air is trapped on the film surface after the film is placed in the processing solution. Air bubbles prevent the chemicals from affecting the emulsion in the area.

To avoid air bubbles, gently agitate and stir film racks after placing them in the processing solution.

FINGERNAIL ARTIFACT

A fingernail artifact is seen when the film emulsion is damaged by the operator's fingernail during rough handling of the film.

To prevent a fingernail artifact, gently handle the film by the edges only.

A fingerprint artifact is seen when the film is touched by fingers contaminated with fluoride or developer.

Solution

To prevent fingerprint artifacts:

- Thoroughly wash and dry hands before processing films.
- Work in a clean area to avoid contaminating the hands.
- Handle the films by the edges only.

THIN, BLACK BRANCHING LINES APPEAR ON THE FILM

- Opening a film packet quickly.
- Opening a film packet before touching another object such as the film processor or countertop in a carpeted office.
- Occurs most frequently during periods of low humidity.

Solution

To prevent static electricity.

- Always open film packets slowly.
- In a carpeted office, touch a conductive object before unwrapping films.

WHITE LINES APPEAR ON THE FILM **(Figs 10.10A and B)**

A scratched film results when the soft film emulsion is removed from the film base by a sharp object such as a film clip or film hanger.

To prevent a scratched film:

- Use care when placing a film in rack in the processing solutions.
- Avoid contact with other film hangers.

LIGHTING

Light Leak

The exposed area appears black (Fig. 10.11).

Problem

A light leak results from:

- Accidental exposure of the film to white light.
- Torn or defective film packets that expose a portion of the film to light.

Solution

To prevent light leaks:

- Examine film packets for minute tears or defects before use.
- Do not use film packets that are torn or defective.
- Never unwrap films in the presence of white light.

FOGGED FILM

The film appears gray and lacks image detail and contrast (Fig. 10.12).



Figs 10.10A and B: Radiographs (A) and (B) showing white lines appear on the film



Fig. 10.11: Radiograph appears black due to light leak



Fig. 10.12: A fogged film lacks image detail and contrast

Problems

Fogged films result from:

- Improper safe lighting and light leaks in the darkroom.
- Improper film storage.
- Outdated films.
- Contaminated processing solutions.
- High developer temperature.

To prevent fogged films:

- Check the filter and bulb wattage of the safe light
- Minimize film exposure to the safe light and check the darkroom for the light leaks.
- Check the expiration date on film packages and store films in a cool, dry and protected area.
- Avoid contamination of processing solutions by replacing tank covers after each use.
- Always check developer temperature before processing films.

Chapter 11

Dental X-ray Film Composition

The dental X-ray film serves as a recording medium or image receptor: the term image refers to picture of likeness of an object, and the term receptor refers to something that responds to a stimulus. Images are recorded on the dental X-ray film when the film is exposed to a stimulus—specifically energy in the form of x-radiation or light.

FILM COMPOSITION

X-ray film is composed of a clear cellulose acetate film base that is coated with an emulsion of silver halide—usually silver bromide grains suspended in a layer of gelatin. The emulsion with its protective cover is attached to the acetate base by an adhesive. The emulsion is sensitive to X-rays.

The X-ray film used in dentistry has four basic components—Base, Adhesive layer, Emulsion and Protective layer.

Film Base

The film base is a flexible piece of polyester plastic that measures 0.2 mm (.007 inch) (Fig. 11.1) thick and is constructed to withstand heat, moisture, and chemical exposure. The film base is transparent and exhibits a slight blue tint that is used to emphasize contrast and enhance image quality. The primary purpose of the film base is to provide a stable support for the delicate emulsion; it also provides strength. The film base is coated on both sides and thus is referred to as a double emulsion. Less radiation is required than with the single-sided emulsion film.

Adhesive Layer

The adhesive layer is a thin layer of adhesive material that covers both sides of the film base. The adhesive layer is added

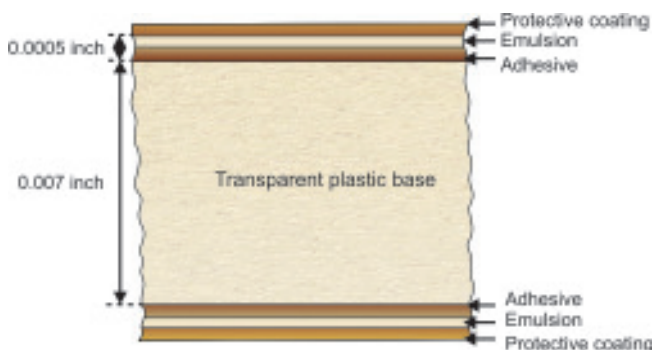


Fig. 11.1: Cross-sectional diagram of film base and emulsion

to the film base before the emulsion is applied and serves to attach the emulsion to the base.

Film Emulsion or Vehicle

The film emulsion is a coating attached to both sides of the film base by the adhesive layer to give the film greater sensitivity to X-radiation. The emulsion is a homogenous mixture of gelatin and silver halide crystals—AgBr and AgI. Size of silver halide particle in E-film, diameter is $1\text{ }\mu\text{m}$ and D-film diameter is $0.7\text{ }\mu\text{m}$.

Gelatin

The gelatin is used to suspend and evenly disperse millions of microscopic silver halide crystals over the film base. During film processing, the gelatin serves to absorb the processing solutions and allows the chemicals to react with the silver halide crystals.

Protective Layer

The protective layer is a thin transparent coating placed over the emulsion. It serves to protect the emulsion surface from manipulation as well as mechanical and processing damage.

TYPES OF FILM

Three types of X-ray film may be used in dental radiography:

- Intraoral film
- Extraoral film
- Duplicating film

Intraoral Film

An intraoral film is one that is placed inside the mouth during X-ray exposure. An intraoral film is used to examine the teeth and supporting structures.

Intraoral Film Packaging

Each intraoral film is packaged to protect it from light and moisture; the film and its surrounding packaging are referred to as a film packet (Fig. 11.2). In dentistry, the terms film packet and film are often used interchangeably. Intraoral film packets



Fig. 11.2: Contents in an X-ray film packet

are typically available in quantities of 25, 100 or 150 films per container.

X-ray Film

The intraoral X-ray film is a double-emulsion (emulsion on both sides) type of film. Double-emulsion film is used instead of single-emulsion (emulsion on one side) film because it requires less radiation exposure to produce an image.

In one corner of the intraoral X-ray film, a small raised bump known as the identification dot is found. The raised bump is used to determine film orientation. After the film is processed, the raised identification dot is used to distinguish between the left and the right sides of the patient. Put the depression of dot in front of the operator and design the teeth in the X-ray film with the alignment of teeth of the operator. By this one can identify the right or left side of the film.

Film Fog

An X-ray film fog results when all or part of the radiograph is darkened by sources other than the primary radiation to which the film was exposed. Fogging degrades the diagnostic image. The film fog results due to:

1. Chemical fog: which results from an imbalance or exhaustion or expired processing solutions.
2. Light fog: which results from unintentional exposure from light leaks and improper safe lighting to which the film emulsion is sensitive either before or during processing.
3. Scattered radiation fog: which results from radiation striking the film from sources other than the intentional exposure of the primary beam. Such as scatter from the patient or unprotected storage of films before or after exposure.

Film Contrast

Film contrast is the characteristic of the X-ray film that enables it to portray differences in subject contrast. It is inherent to each type of film and is determined by the manufacturer of the film. Film with high contrast is desirable for diagnosis.

Film contrast is usually expressed as the slope of the line in the diagnostically useful part of the characteristic curve.

Contents of Film Packet

Paper Film Wrapper

The paper film wrapper within the film packet is a black paper protective sheet that covers the film and shields the film from light (Fig. 11.3).

Lead Foil Sheet

The lead foil sheet is a single piece of lead foil that is found within the film packet and is located behind the film wrapped in black protective paper. The thin lead foil sheet is positioned behind the film to shield the film from back-scattered (secondary) radiation that results in film fog.

Outer Package Wrapping

The outer package wrapping is a soft vinyl or paper wrapper that hermetically seals the film packet, protective black paper, and lead foil sheet. This outer wrapper serves to protect the film from exposure to light and saliva.

The outer wrapper of the film packet has two sides: tube side and label side.

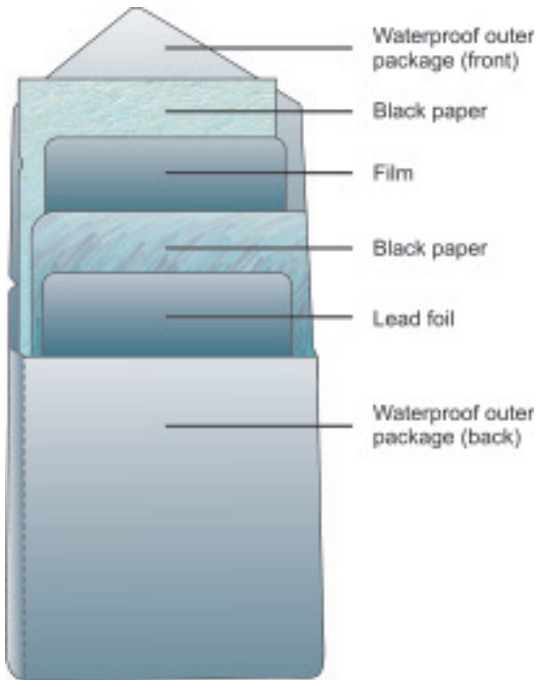


Fig. 11.3: An X-ray film packet

Tube side: The tube side is solid white and has a raised bump in one corner that corresponds to the identification dot on the X-ray film. When placed in the mouth, the white side (tube side) of the film packet must face the teeth and the tubehead.

Label side: The label side of the film packet has a flap that is used to open the film packet to remove the film prior to processing. The label side is color coded to identify films

outside of the plastic packaging container; color codes are used to distinguish between one-film and two-film packets and between film speeds. When placed in the mouth, the color coded side (label side) of the packet must face the tongue for lower teeth and face the palate for upper teeth.

Intraoral Film Types

Three types of intraoral films are available:

Periapical Film

The periapical film is used to examine the entire tooth (crown and root) and supporting bone. The term periapical is derived from the Greek word *peri* meaning around and the Latin word *apex* meaning the terminal end of a tooth root. As the term suggests, this type of film shows the tip of the tooth root and surrounding structures as well as the crown.

Bitewing Film

The bitewing film is used to examine the crowns of both the maxillary (upper) and mandibular (lower) teeth on one film. The bitewing film is particularly useful in examining the interproximal, or adjacent, tooth surfaces. The bitewing film has a "wing", or tab, attached to the tube side of the film. The patient "bites" on the "wing" to stabilize the film, hence the term bitewing. Bitewing films may be purchased with tabs attached to the film or may be constructed from a periapical film and bitewing loop.

Occlusal Film

The occlusal film is used for examination of large areas of the maxilla (upper jaw) or mandible (lower jaw). The occlusal

film is so named because the patient "occludes" or bites on the entire film. The occlusal film is larger than periapical or bitewing films.

Intraoral Film Sizes

Intraoral film is manufactured in sizes to accommodate the varying mouth sizes of children, adolescents and adults. The larger the number the larger the size of the film. Different sizes of film are used with periapical, bitewing and occlusal exposure.

Intraoral film packets come in five basic sizes: child size no. 0, narrow anterior film no. 1, size no. 2, occlusal film packets no. 4 and preformed long bitewing films no. 3 are available.

The intraoral film packets are light tight and resistant to salivary seepage. These packets have some degree of flexibility and are easy to open in the darkroom.

Periapical Film

Three sizes of periapical film (0, 1 and 2) are available:

Size 0: This periapical film is the smallest intraoral film available and is used for small children (22×35 mm).

Size 1: This periapical film is used primarily to examine the anterior teeth in adults (24×40 mm).

Size 2: This periapical film, also known as the standard film, is used to examine the anterior and posterior teeth in adults (32×41 mm).

Bitewing Film

Four sizes of bitewing film (0, 1, 2 and 3) are available. With the exception of the size 3 film. The size and shape of the bitewing film are identical to the size and shape of the periapical film.

Size 0: This bitewing film is used to examine the posterior teeth in very small children.

Size 1: This bitewing film is used to examine the posterior teeth in children. When positioned vertically, it can be used to examine the anterior teeth in adults.

Size 2: This bitewing film is used to examine the posterior teeth in adults. This is the most frequently used bitewing film.

Size 3: This film is longer and narrower than the standard Size 2 film and is used only for bitewings. This bitewing film shows all of the posterior teeth on one side of the arch in one radiograph.

Occlusal Film

The occlusal film is the largest intraoral film and is almost four times as large as a standard Size 2 periapical film (57 × 76 mm).

Size 4: This occlusal film is used to show large areas of the upper or lower jaw (Fig. 11.4).

Intraoral Film Speed (Sensitivity)

Film speed refers to the amount of radiation required to produce a radiograph of standard density. Film speed, or sensitivity, is determined by the following:

- The size of the silver halide crystals.
- The thickness of the emulsion.
- The presence of special radiosensitive dyes.

Film Speed

More sensitive films require less mAs and are said to have greater film speed. These are fast films. Slow films require more mAs and are less sensitive to radiation. The size of the

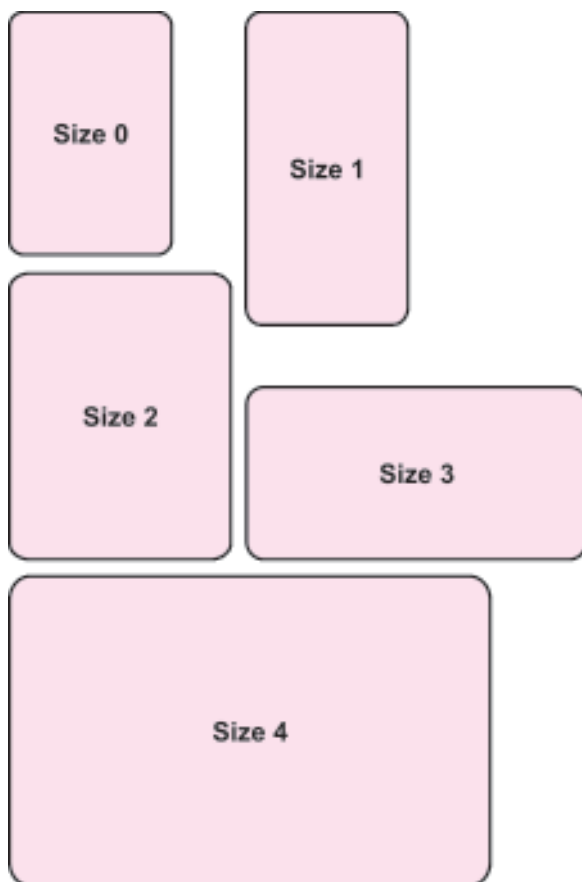


Fig. 11.4: Intraoral film sizes: size 0 for child, size 1 for narrow anterior, size 2 for adult, size 3 for bitewing and size 4 for occlusal

silver bromide crystals is the main factor in determining the film speed, the larger the crystals the faster the film.

Slow film at 65 kVp and 10 mA would take an average exposure time of about 3 seconds per film and the fast film about 1/3 of second of exposure per film. The intermediate speed film take about 1½ second.

Film speed determined how much radiation and how much exposure time are necessary to produce an image on a film.

X-ray films are given speed ratings ranging from A speed (the slowest) to F speed (the fastest). Only D-speed film and E-speed film are used for intraoral radiography.

Chapter 12

Extraoral Radiography

INTRODUCTION

An extraoral radiograph is one that is placed outside the mouth during X-ray exposure. Extraoral radiography is used to image large areas of the skull of jaws.

Purpose and Use

- To evaluate large areas of the skull and jaws.
- To evaluate growth and development.
- To evaluate impacted teeth.
- To detect diseases, lesions and conditions of the jaws.
- To examine the extent of large lesions.
- To evaluate trauma.
- To evaluate the temporomandibular joint area.
- To evaluate if the patient has swelling or discomfort and is unable to tolerate the placement of intraoral films.

Advantages

1. Radiography gives evidence of abnormalities of the anatomic structure of the bones and shows alterations in their radiability such as osteolytic changes appear radiolucent while osteosclerosis or increase in calcifications appear radiopaque.
 - Expansions of cortical plates and reaction of periosteum are visible in the radiograph.
 - Sinus, if filled with fluid or soft tissue growth (polyp mucocoele), may become appear radiographically.
2. Radiograph also gives some indication of the development of the disease. The lesion may be circumscribed and appear as well-defined radiopaque shadow or it may spread by infiltration into the adjacent tissue without well-defined border in the radiograph.

3. The radiographic shadow of malignancy appears as indefinite line of the lesion, invasion of adjacent tissue, breaking through the cortex, involvement of bone both inside and outside and pathological fracture.
4. In the radiographic examination the relation of the lesion to other adjacent structures such as foramina, nerve canals, the roots of the teeth, and the nasal cavity.
5. The involvement of unerupted teeth with the dentigerous cyst can be visualized in the radiograph or the displacement of the involved teeth within the lesion local destruction of the lamina dura of the alveolar socket occurs at the apex of periapical infections. The lamina dura may be resorbed completely in diseases causing general bone resorption such as hyperparathyroidism. In malignant disease resorption of the bone and teeth occurs and a repair by deposit of new bone seen in the radiograph.
6. The calcified tissue may appear more radiopaque due to forming bone trabecular as in ossifying fibroma.
7. Contrast media are used to visualize the ducts and acini of the salivary glands and various abnormalities can be diagnosed by this method.
8. A foreign body may be recognized such as calcified tissue, a sequestrum or even tooth rudiments as seen in an odontoma can be visualized as radiopaque substances.

The main anatomic landmark used in the patient positioning during extraoral radiography is the canthomeatal line. This is the line which joins the central point of the external auditory canal to the outer canthus of the eye. The canthomeatal line forms a 10-degree angle with the Frankfort line. Frankfort line is the line that connects the superior border of the external auditory canal with the infraorbital rim.

EXTRAORAL FILM PACKAGING

Unlike intraoral films, extraoral films are designed to be used outside of the mouth and therefore are not enclosed in moisture-proof packets. Extraoral film used in dental radiography is available in 5×7 inch and 8×10 inch sizes.

FILM TYPES

Two types of film may be used in extraoral radiography: screen film and nonscreen film.

Screen Film

The majority of extraoral films are screen films. A screen film is a film that requires the use of a screen for exposure. A screen film is placed between two special intensifying screens in a cassette. When the cassette is exposed to X-rays, the screens convert the X-ray energy into light, which in turn the screen film. Screen film is sensitive to fluorescent light rather than direct exposure to X-radiation.

Films used in a screen-film combination are sensitive to specific colors of fluorescent light. Some screen films are sensitive to blue light (Kodak X-Omat and Ektamat films), whereas others are sensitive to green light (Kodak Ortho and T-Mat films). Blue-sensitive film must be paired with screens that produce blue light, and green-sensitive film must be paired with screens that produce green light. Properly matched film-screen combinations are imperative to obtain high-quality images and minimize exposure to the patient.

Nonscreen Film

A nonscreen film is an extraoral film that does not require the use of screens for exposure. A nonscreen extraoral film

is exposed directly to X-rays; the emulsion is sensitive to direct X-ray exposure rather than to fluorescent light. A nonscreen extraoral film requires more exposure time than a screen film and is not recommended for use in dental radiography.

EXTRAORAL FILM EQUIPMENT

In extraoral radiography, screen films are used in combination with two special equipment items: intensifying screens and cassettes. The equipment required for extraoral radiography are:

X-ray Unit

A standard intraoral X-ray machine may be used for a variety of extraoral projections (i.e. transcranial and lateral jaw projections). The cephalostat includes a film holder and head positioner that allow the dental radiographer to position both film and patient easily.

Film

Most extraoral exposure are made with screen film placed in a cassette with intensifying screens. Screen film is sensitive to the light emitted from intensifying screens. The use of screen film and intensifying screens minimizes the X-ray exposure necessary to produce a diagnostic radiograph. Blue sensitive film must be paired with screens that produce blue light, and green-sensitive film must be paired with screens that produce green light. Extraoral film size varies, the sizes most often used are 5 × 7 inch and 8 × 10 inch.

A nonscreen film requires more exposure time than a screen film.

Intensifying Screens

An intensifying screen is a device that transfers X-ray energy into visible light; the visible light, in turn, exposes the screen film. As the word intensifying suggests, these screens intensify the effect of X-rays on the film. With the use of intensifying screens, less radiation is required to expose a screen film, and the patient is exposed to less radiation (Fig. 12.1).

In extraoral radiography, a screen film is sandwiched between two intensifying screens of matching size and secured in a cassette. Intensifying screen is a smooth plastic sheet coated with minute fluorescent crystals known as phosphors. When exposed to X-rays, the phosphors fluoresce and emit visible light in the blue or green spectrum; the emitted light then exposes the film. One of the properties of X-rays is that they cause certain materials, like phosphors to fluoresce.

Conventional calcium tungstate screens have phosphors that emit blue light. The newer rare earth screens have

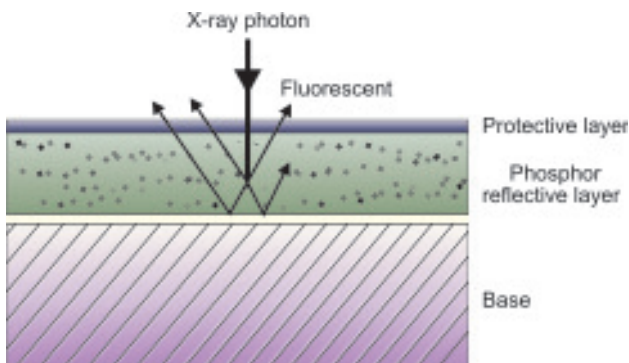


Fig. 12.1: The principle of intensifying screen

phosphors that are not commonly found in the earth (hence the name rare earth) and emit green light. Rare earth intensifying screens are more efficient than calcium tungstate intensifying screens for converting X-rays into light. As a result, rare earth screens require less X-ray exposure than calcium tungstate screens and are considered faster. The use of rare earth screens means less exposure to X-radiation for the patient.

Cassette

A cassette is special device that is used to hold the extraoral film and the intensifying screens. Cassettes are available in a variety of sizes that correspond to film and screen size. A cassette may be flexible or rigid; most cassettes are rigid with the exception of the panoramic cassette, which may be flexible.

A rigid cassette is more expensive than a flexible one but usually lasts longer. A rigid cassette protects screens from damage better than a flexible one.

Both rigid and flexible cassettes must be light-tight not only to protect the extraoral film from exposure but also to hold the intensifying screens in perfect contact with the extraoral film. Contact between the screen and the film is critical; lack of contact between screen and film results in a loss of image sharpness.

A rigid cassette has a front and a back cover. The front cover is placed so that it faces the tubehead and is usually constructed of plastic to permit the passage of the X-ray beam. The back cover is constructed of heavy metal and serves to reduce scatter radiation. Intensifying screens are installed inside the front and back covers of the cassette. The film is positioned between the two intensifying screens. Each screen exposes one side of the film (Fig. 12.2).



Fig. 12.2: The film cassette

The cassette must be marked to orient the finished radiograph; a metal letter L is attached to the front cover of the cassette to indicate the patient's left side, and a metal letter R is used to indicate the patient's right side.

Grid

A grid is a device used to reduce the amount of scatter radiation that reaches an extraoral film during exposure. As previously discussed, scatter radiation causes film fog and reduces film contrast. A grid can be used to decrease film fog and increase the contrast of the radiographic image.

A grid is composed of a series of thin lead strips embedded in a material (e.g. plastic) that permits the passage of the X-ray beam. The grid is placed between the patient's head and the film. During exposure, the grid permits the passage of the X-ray beam between the lead strips.

EXTRAORAL PROJECTION TECHNIQUES

The purpose, film, placement, head position, beam alignment and exposure factors differ for each projection used in lateral

jaw radiography, skull radiography and temporomandibular joint radiography.

Lateral Jaw Radiography

Lateral jaw radiography is used to examine the posterior region of the mandible and is valuable for use in children, in patients with limited jaw opening due to a fracture or swelling, and in patients who have difficulty in stabilizing or tolerating intraoral film placement. The film in this extraoral projection technique is positioned lateral to the jaw during exposure.

- Body of mandible projection.
- Ramus of mandible projection.

Body of Mandible Projection

Purpose: The purpose of this film is to evaluate impacted teeth, fractures and lesions located in the body of the mandible. This projection demonstrates the mandibular premolar and molar regions as well as the inferior border of the mandible.

Film placement: The cassette is placed flat against the patient's cheek and is centered over the body of the mandible. The cassette must also be positioned parallel with the body of the mandible. The patient must hold the cassette in position with the thumb placed under the edge of the cassette and the palm against the outer surface of the cassette.

Head position: The head is tipped approximately 15 degree toward the side being imaged. The chin is extended and elevated slightly.

Beam alignment: The central ray is directed to a point just below the inferior border of the mandible on the side opposite the cassette. The beam is directed upward (–15 to –20 degrees) and centered on the body of the mandible. The beam must be directed perpendicular to the horizontal plane of the film.

Exposure factors: The exposure factors for this projection vary with the film, intensifying screens and equipment used.

Mandibular Ramus Projection

This gives a view of the ramus from the angle to the condyle. It is also useful for examining the impacted maxillary and mandibular third molar regions.

Techniques

The cassette is placed over the ramus and far enough posteriorly to include the condyle. The lower border of the cassette should be approximately parallel with the inferior border of the mandible and should extend at least 2 cm below the border. The central ray is directed posteriorly toward the center of the ramus on the side of interest from a point 2 cm below the inferior border of the first molar region of the mandible.

Skull Radiography

Skull radiography is used to examine the bones of the face and skull and is most often used in oral surgery and orthodontics. Although some skull films can be exposed using a standard intraoral X-ray machine, most require the use of an extraoral unit and cephalostat.

The most common skull radiographs used in dentistry are:

- Lateral cephalometric projection.
- Posteroanterior projection.
- Waters projection.
- Submentovertex projection.
- Reverse Towne's projection.

POSTEROANTERIOR PROJECTION

Purpose

This view is excellent for evaluating the inner and middle ear because the petrous can be viewed through this profil. This projection also demonstrates the frontal and ethmoid sinuses, the orbits and the nasal cavity.

Uses

- To examine the skull for disease, trauma or developmental abnormalities.
- For detecting progressive changes in the mediolateral directions of the skull, e.g. asymmetric growth.

The posteroanterior view is so named because the X-ray beam passes from the posterior to anterior direction.

Technique

In posteroanterior projection, the patient's forehead and nose are positioned against the film cassette. The central ray is directed to the midline of the skull so that the X-ray beam passes through the canthomeatal plane perpendicular to the plane of the film in the horizontal and vertical dimensions. The source should be coincident with the midsagittal plane of the head at the level of the bridge of the nose (Fig. 12.3).

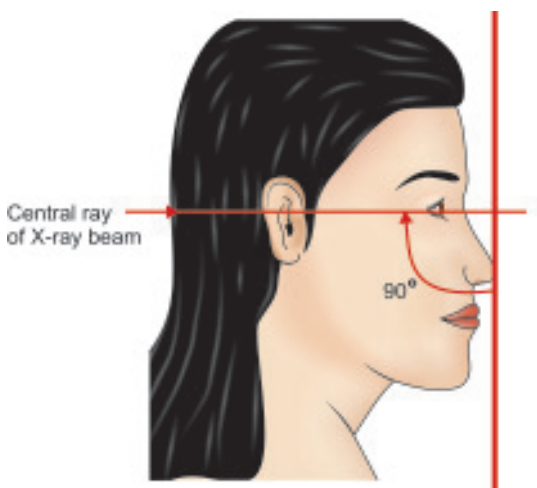


Fig. 12.3: Diagram of posteroanterior projection

LATERAL SKULL PROJECTION

This projection gives a view of the calvarium and base of the skull, paranasal sinuses (frontal and sphenoidal) can be evaluated. The pterygopalatine fossa and hard palate can also be visualized. Orthodontists use it to assess facial growth. Shape and depth of the sella turcica may be evaluated.

The lateral cephalometric projection reveals the facial soft tissue profile otherwise it is identical to the lateral skull view.

Technique

In this projection, the head is positioned so that the midsagittal plane is parallel to the film and a line connecting the external auditory meatus is perpendicular to the film.

The central ray is perpendicular to the midsagittal plane and perpendicular to the plane of the film and is centered over the external auditory meatus.

OCCIPITOMENTAL PROJECTION (WATERS PROJECTION)

It is particularly useful for evaluating the maxillary sinuses. It also demonstrates the frontal and ethmoidal sinuses, orbital floors, zygomatic bone and zygomatic arches. It is used to evaluate traumatic injuries in these areas or any foreign body in the sinuses.

The head is oriented with sagittal plane perpendicular to the plane of the film. The head is extended and the chin is raised so that the canthomeatal line forms an angle of 37 degrees with the horizontal and the central ray. The central ray should be perpendicular to the film enters the skull 3 cm above the external occipital protuberance and exits through the tip of the nose (Fig. 12.4).

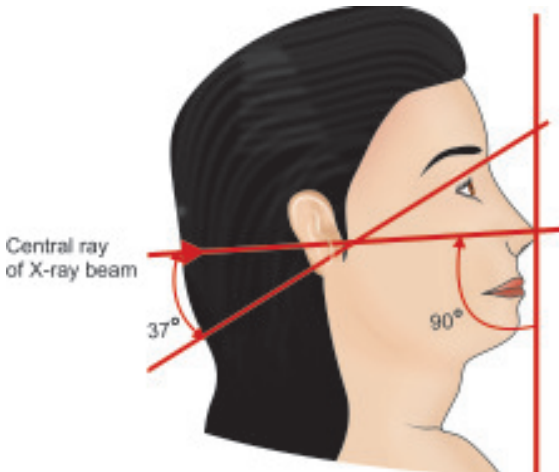


Fig. 12.4: Diagram of Waters projection

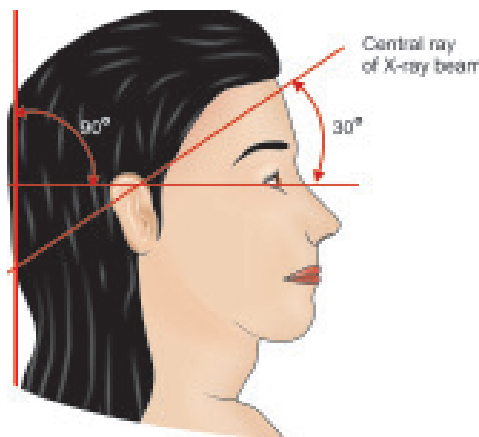


Fig. 12.5: Towne's projection

TOWNE'S PROJECTION

The projection is an anteroposterior view. This view is useful to observe the occipital area of the skull. The necks of the condyloid processes can be viewed.

Technique

The canthomeatal line is perpendicular to the film. The film is placed posteriorly on the occipital area of the head. The central ray is directed 30 degree to the canthomeatal line and passes through it at a point between the external auditory canals (Fig. 12.5).

REVERSE TOWNE'S PROJECTION

This view is used to examine a suspected fracture of neck of condyle and reveals a medially displaced condyle. This projection also reveals the lateral wall of the maxillary antrum.

Technique

The head is centered in front of the cassette so that the canthomeatal line oriented downward 25 to 30 degrees.

The patient is asked to open the mouth for better visualization of the condyles. The central ray is directed toward the film in sagittal plane through the occipital bone.

SUBMENTOVERTEX PROJECTION (BASE PROJECTION)

This projection is also known as jug handle view or base or full axial projection.

It is used to visualize the base of skull, the displacement of a fractured zygomatic arch, the position and orientation of the condyles, the sphenoidal sinus, the lateral wall of the maxillary sinuses.

Technique

The head and neck of the patient is extended backward as far as possible, with the vertex of the skull on the center of the cassette. The midsagittal plane of the head must remain perpendicular to the floor. The canthomeatal line is parallel to the film and perpendicular to the central ray. The central ray enters the skull in the midline between the mandibular angles (Fig. 12.6).

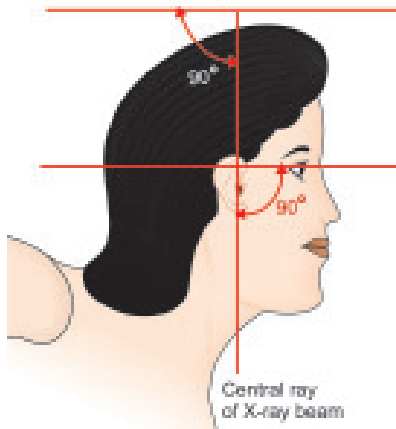


Fig. 12.6: Base projection

DUPLICATING FILM

Duplication of the radiographs is essential in recent years from the litigation point of view and also to protect ourselves. The defendant-dentists records are of the almost importance. Duplication of the radiographs is a relatively easy process which requires a few additions to normal darkroom equipment, such as duplicating film, a photographic printing frame, appropriate size film hangers a light source (ultraviolet). All size of the radiographic films are duplicated by commercially available duplicating devices (Figs 12.7A and B).

Radiographic duplicating film is available in 8×10 or 5×12 inches sheets and individually wrapped periapical size duplicating film.

The emulsion on duplicating film is present only on one side of the film. The emulsion side appears dull while the nonemulsion side appears shiny. The duplicating film has a direct positive emulsion, therefore, if more film density is needed, the exposure time is shortened and if

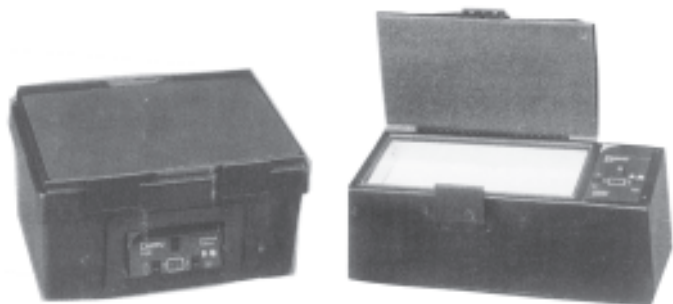


Fig. 12.7A: Radiographic duplicator

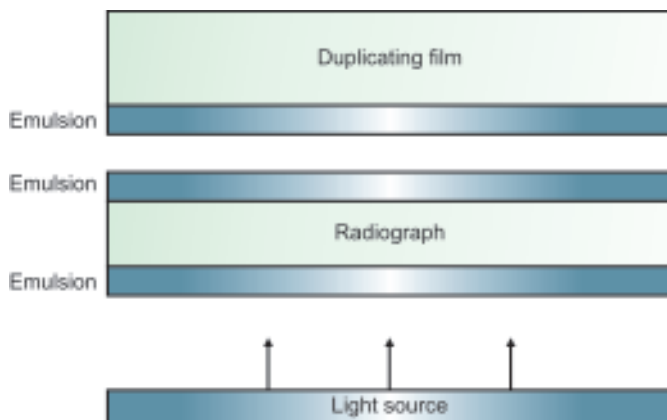


Fig. 12.7B: Duplication of film

decreased film density is required, the exposure time is increased. This is the opposite of time required for exposing dental film to X-rays. Duplicating films have no orientation dot for identification, the film must be labeled as right and left.

Technique of Duplicating the Film

The radiographs to be duplicated are placed in close contact with the emulsion side of the duplicating films positioned so that the light strikes the original or the raised part of the mounting dot faces the light source first. This is done in safelight. A photographic printing frame will hold the original radiograph against the duplicating film. The films are exposed to light for about 6 to 8 seconds. The duplicating film is processed after the exposure is made in the same manner as in normal manual or automatic technique. Close positive contact is essential between the original radiograph and the duplicating film.

Chapter 13

Radiographic Techniques

A fundamental rule in radiography is that the central ray should pass through the region to be examined and that the film should be placed in a position so as to record the findings with the least amount of distortion. The different radiographic examinations in dentistry are—intraoral (e.g. periapical, bitewing, occlusal) and extraoral radiographs (e.g. PA projection, Towne's projection, waters projection, etc).

Full-Mouth Survey

A complete oral diagnosis can be made by the full-mouth intraoral radiographic survey. The full-mouth survey by the radiographs is the requirement for dental examination or treatment plan (Fig. 13.1).

The full-mouth radiographic survey is usually composed of 14 or more periapical films. A periapical film shows the entire tooth from occlusal surface or incisal edge to the apex and 2 to 3 mm of periapical bone. This film is necessary to diagnose normal or pathologic conditions of tooth crowns and root, bone, periapical area and tooth formation and eruption.

The bitewing film can be taken only if there are opposing teeth to hold the film in position with their occluding surfaces. This film projection shows the upper and lower teeth in occlusion. Only the crowns of teeth of the upper and lower arches are seen (Figs 13.2A and B). Bitewing film is used for detecting interproximal caries, periodontal bone loss, recurrent decay under restorations and faulty restorations. For full-mouth radiographic survey four posterior bitewing films are required.

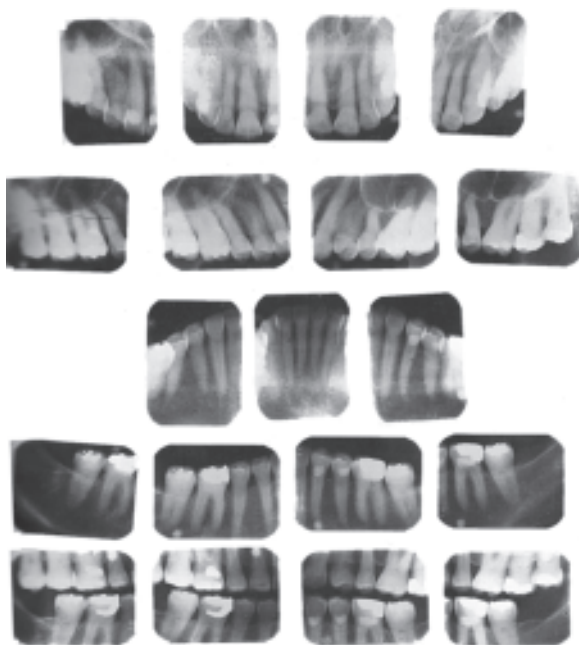
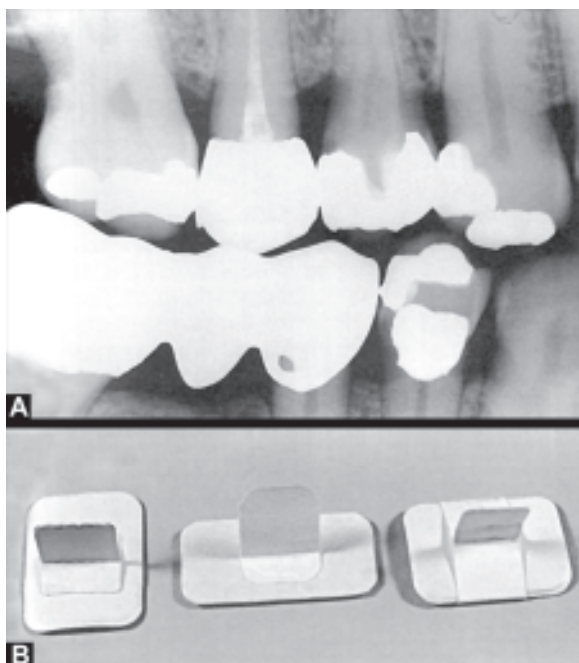


Fig. 13.1: Showing a 19-film full-mouth survey

An edentulous area requires full-mouth survey to detect residual root tips, unerupted teeth or other pathologic conditions in the bone. A 13 film for edentulous survey is required.

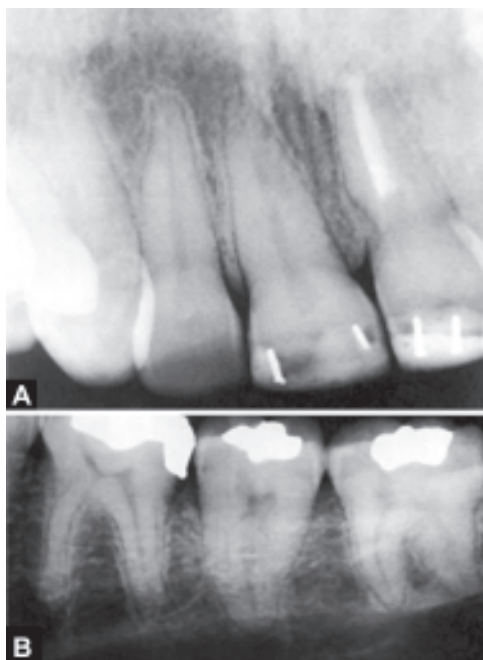
In pediatric patients up to age 5 who need a full mouth series, the use of pediatric size film number 0 for anterior, posterior and bitewing projections. About 12 periapical films are required, and only 2 bitewing projections are taken for molar on each side.



Figs 13.2A and B: Showing (A) Bitewing radiograph. Note that only the crowns, alveolar ridge and a small part of the roots opposing teeth are seen. (B) Types of bitewing films; left, vertical; middle, long posterior and right, standard

Periapical Examination

A periapical film shows the entire tooth from occlusal surface or incisal edge to the apex and 2 to 3 mm of periapical bone, i.e. periapical area surrounding the root apex. This film is used to diagnose normal or pathologic conditions of tooth crowns and root, bone and tooth formation and eruption (Figs 13.3A and B). A full-mouth radiographic survey is useful composed of the periapical film.



Figs 13.3A and B: Anterior (A) and posterior (B) periapical radiographs. Note that the entire tooth and surrounding periapical bone are shown

The main purpose of the intraoral periapical examination is to obtain a view of the apices of the roots of the teeth and their surrounding structures. Two basic techniques are employed—the paralleling technique and bisecting-angle technique.

The choice of size of the film is largely applicable to both techniques, a film that is narrower than the standard film may be necessary to attain true parallelism where examination is made according to the paralleling technique.

PARALLELING TECHNIQUE

The paralleling technique also has been referred to as the "right-angle technique", the "long-cone technique" and the "Fitzgerald technique". Dr Gordon Fitzgerald was largely responsible for developing the technique as a practical intraoral procedure.

The paralleling technique is also known as the extension cone paralleling (XCP) technique.

Principles

As the term paralleling suggests, this technique is based on the concept of parallelism. The basic principles of the paralleling technique can be described as follows:

- The film is placed in the mouth parallel to the long axis of the tooth being radiographed.
- The central ray of the X-ray beam is directed perpendicular (at a right angle) to the film and long axis of the tooth.
- A film holder must be used to keep the film parallel with the long axis of the tooth. The patient cannot hold the film.

Because of the anatomic configuration of the oral cavity (e.g. curvature of the palate), the object-film distance (distance between the film and the tooth) must be increased to keep the film parallel with the long axis of the tooth. Because the film is placed away from the tooth, image magnification and loss of definition result. Increased object-film distance results in increased image magnification.

To compensate for image magnification, the target film distance (distance between the source of X-rays and the film) must also be increased to ensure that only the most parallel rays will be directed at the tooth and film. As a result, a long (16 inch) target film distance must be used with the paralleling technique.

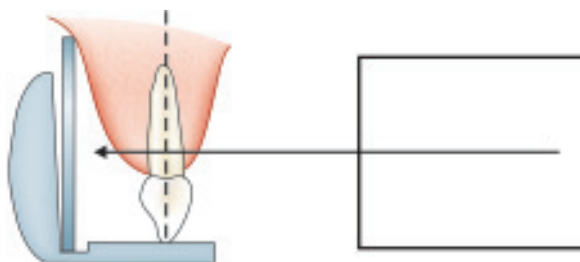


Fig. 13.4: Showing positions of the film, teeth and central ray of the X-ray beam in the paralleling technique. The film and long axis of the tooth are parallel. The central ray is perpendicular to the tooth and film. An increased target-film distance (16 inches) is required

The primary objective of the paralleling technique is to obtain a true radiographic orientation of the teeth with their supporting structures. This is accomplished by placing the film parallel to the long-axis of the teeth. To attain parallelism, the film is moved away from the crowns of the teeth, while the edge of the film against the soft tissue is approximately in the same position in the palate or floor of the mouth as it is in the bisecting-angle technique. To avoid enlargement of the image as a result of moving the film away from the object:

1. A long tube (16 to 20 inches) is employed, the rays that strike the object are the nearly parallel central rays, and the divergent rays that cause magnification and distortion of the image are largely eliminated (Fig.13.4). By employing the longer tubes and thereby increasing the target-film distance, the dose rate is decreased following the inverse square law. Therefore, a greater exposure would be necessary in order that the dose to the film exposure is avoided by the use of a fast dental film.

To attain film-tooth parallelism, several methods and devices are used to aid in positioning the film packet and also to hold it in place. A method that can be used is to place a cotton roll between the emulsion side of the film packet and the lingual surfaces of the crowns of the teeth and have the patient to hold the packet in place with the thumb or index finger.

2. Special holders have been designed to fulfill the requirements for positioning of the film. One of them is the Rinn holder, one end of this device is used for positioning the film for the anterior region and the other is used for positioning the film for the posterior regions (C.D. Rinn holder) (Figs 13.5A to C).
3. A hemostat serves as an excellent film holder since the film packet can be held firmly between its beaks at varied positions so as to attain proper placement of the film.

Hemostat is particularly useful for examination of patients who are unable to open the mouth sufficiently to permit the film packet to be introduced and positioned by means of the fingers or other methods because of the small size of the beak and shank of the hemostat, the film packet can be inserted into the mouth and rotated into the proper position.

The technique permits accurate pointing of the central rays because they are directed at right angles to the surface of the film and not toward an imaginary line or plane.

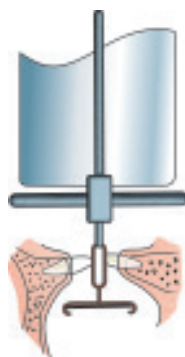
BISECTING TECHNIQUE

Principles

The bisecting technique is based on a simple geometric principle known as the rule of isometry. The rule of isometry states that two triangles are equal if they have two equal



Fig. 13.5A: A complete set of Rinn holder and single devices for anterior, posterior and bitewing projections



Figs 13.5C(i)

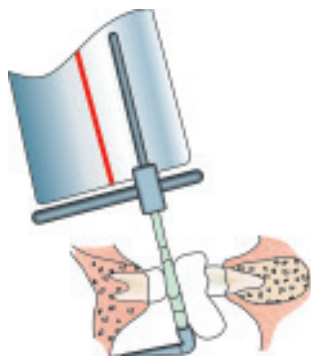
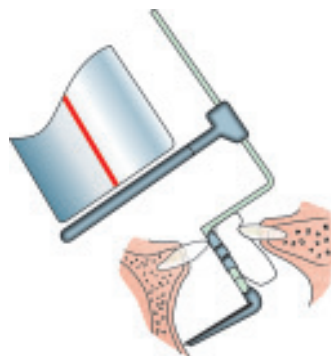
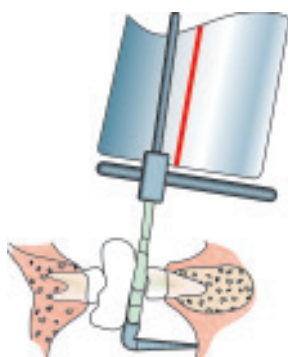
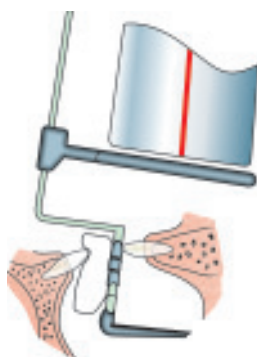


Fig. 13.5B

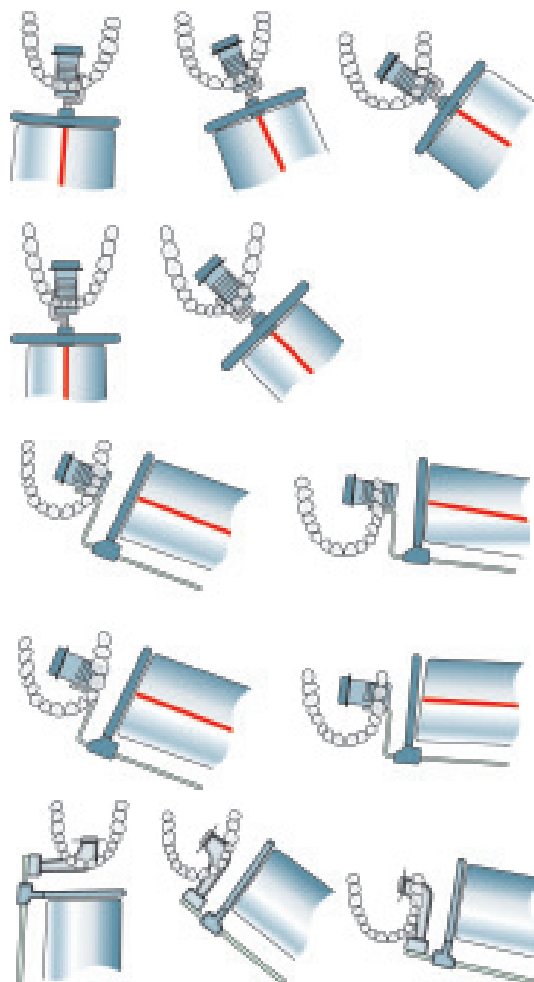
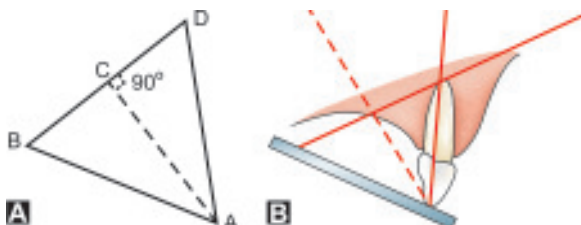


Fig. 13.5C

Figs 13.5B and C: Positioning of the device for anterior, posterior and bitewing projection



Figs 13.6 A and B: (A) The film (line BA) is placed along the lingual surface of the tooth. At the point where the film contacts the tooth, the plane of the film and the long axis of the tooth (DA) form an angle (BAD). The imaginary bisector divides this angle into two equal angles (BAC and DAC). The central ray (BD) is directed perpendicular to the imaginary bisector and completes the third sides (BC and CD) of the two triangles. (B) Bisecting technique showing the central ray directed at a right angle to the imaginary bisector

angles and share a common side (Figs 13.6A and B). The bisecting technique can be described as follows:

- The film must be placed along the lingual surface of the tooth.
- At the point where the film contacts the tooth, the plane of the film and the long axis of the tooth form an angle.
- The dental radiographer must visualize a plane that divides in half, or bisects, the angle formed by the film and the long axis of the tooth. This plane is termed the imaginary bisector. The imaginary bisector creates two equal angles and provides a common side for the two imaginary equal triangles.
- The dental radiographer must then direct the central ray of the X-ray beam perpendicular to the imaginary bisector. When the central ray is directed 90 degree to the imaginary bisector, two imaginary equal triangles are formed (Fig. 13.7).

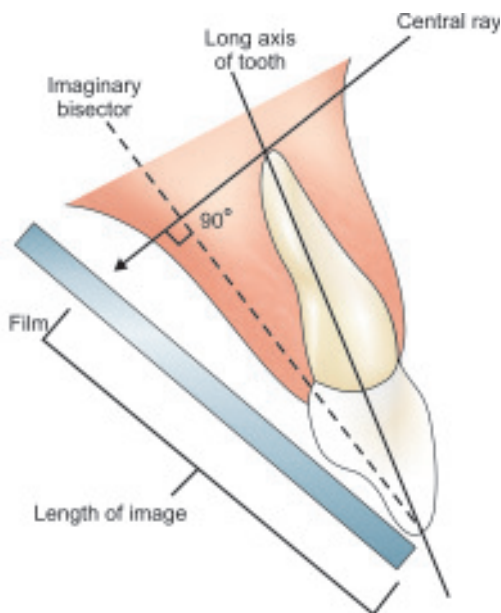


Fig. 13.7: Showing the image on the film is equal to the length of the tooth when the central ray is directed at 90 degrees to the imaginary bisector. A tooth and its radiographic image will be equal in length when two equal triangles are formed that share a common side (imaginary bisector)

- The two imaginary triangles that result are right triangles and are congruent. The hypotenuse of one imaginary triangle is represented by the long axis of the tooth; the other hypotenuse is represented by the plane of the film.

Vertical Angulation of the X-ray Tubehead

Vertical angulation is the angle formed by continuing the line of the central X-ray beam to the occlusal plane. This

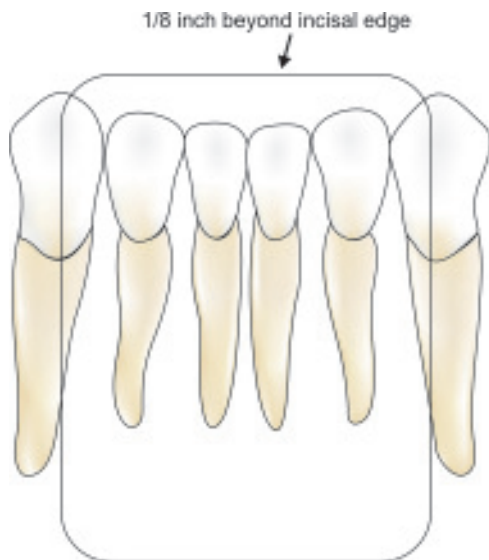


Fig. 13.8: Showing approximately 1/8 inch of the film must appear beyond the incisal edges of the teeth

depends upon patients head position, individual tooth position and inclination. In deciding vertical angulation the film should be such placed that 2 to 3 mm (1/8 inch) of the film be visible beyond the incisal edge or occlusal surface of the tooth (Fig. 13.8).

Horizontal Angulation

The central ray should be aimed through the interproximal contact areas in the horizontal plane to avoid overlapping of the teeth. This depends on the shape of the arch and the position of the teeth (Fig. 13.9).

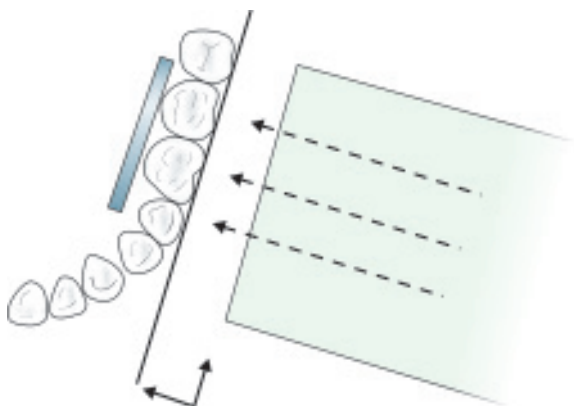


Fig. 13.9: Showing in this diagram, the X-rays pass through the contact areas of the premolars because the central ray is directed through the contacts and perpendicular to the film. If the central ray is not directed through the contacts, overlap of the premolar contacts occurs

Disadvantages of Paralleling Technique

- (a) Positioning of the film packet is very uncomfortable to the patient especially for posterior teeth.
- (b) The anatomy of the mouth sometimes makes the technique impossible, e.g. a shallow flat palate, small mouths for children.
- (c) The apices of the teeth sometimes appear very near to the edge of the film.
- (d) For exposure to lower third molar regions positioning of the holder is different.
- (e) With a short focal spot to skin distance, the technique cannot be performed.
- (f) In paralleling technique difficulty is in placement and the degree of discomfort caused by the devices used to hold the film parallel to the long axis of the tooth.

- (g) The paralleling is more difficult to learn and takes clinically longer to do.
- (h) Some operators object to the long, bulky 16-inch PID that is used in the paralleling technique.
- (i) In paralling technique with 16-inch FFD, longer exposure times are necessary, resulting in greater chance of patient movement, with the use of faster film, this is no longer true.

Advantage of the Paralleling Technique

- (a) A center images are produced with little magnification.
- (b) The periapical tissues are accurately shown with minimum image size distortion, i.e. a true linear relationship without elongation or foreshortening.
- (c) The periodontal bone levels are well-represented.
- (d) The crowns of the teeth with proximal caries are well shown.
- (e) The shadow of the zygomatic butterus appears above the apices of the molar teeth.
- (f) The horizontal and vertical angulations of the X-ray tubehead are automatically determined by the positioning devices.
- (g) The X-ray beam is accurately centered on the film.
- (h) The relative positions of the film packet, teeth and X-ray beam are always maintained irrespecting the position of head.
- (i) It produces better diagnostic images, less exposure to critical organs such as the thyroid gland and the lens of the eye, a smaller exit dose and easier standaralization.
- (j) It produces no superimposition of zygomatic arch because central ray is perpendicular to the long axis of the molars.
- (k) Serial comparison radiographs of the same area give greater validity.

Positioning Techniques in Periapical Radiography for Permanent Teeth

The appropriate size of the film packet and holder (Rinn XCP) are selected.

Incisor and Canines (Maxillary and Mandibular)

An anterior holder and a small film packet (22 × 35 mm) with its long axis vertical should be used.

Premolars and Molars (Maxillary and Mandibular)

A posterior holder and a large film packet (31 × 41 mm) with its long axis horizontal should be used.

Procedure

- (a) The white smooth surface of the film packet must face toward the X-ray tube head.
- (b) The embossed oriented dot at one end of the film packet is placed opposite the crowns of the teeth.
- (c) The patient is positioned so that the occlusal plane is horizontal and parallel to the floor. The head is supported by the headrest.
- (d) The holder and film packet are placed in the mouth so that the film is parallel to the teeth.

For maxillary teeth, the film packet is positioned sufficient posterior to accommodate its height in the vault of the palate.

Indications of Paralleling Technique

1. Detection of periapical infection around the root apex.
2. Assessment of the periodontal status around the tooth surface.

3. Assessment of the presence and position of unerupted, impacted or ankylosed tooth.
4. Assessment of root morphology such as dilaceration, extraroot, hypercementosis.
5. After trauma to the teeth and dentoalveolar fracture.
6. Preoperative and postoperative assessment after apical surgery, e.g. apicectomy.
7. Evaluation of periapical cyst, granuloma or abscess.
8. Evaluation of implant postoperatively.

ADVANTAGES AND DISADVANTAGES OF BISECTING TECHNIQUE

The paralleling technique is the technique of choice for periapical radiography. The bisecting technique should be considered an ancillary method that can be used in special circumstances when it is not possible to use the paralleling technique.

Advantages

Easier to perform. The use of the patient's finger or simple bite blocks for holding the film packets in position avoids the use of the paralleling instruments. For patients with small mouths, for children, and for patients with low palatal vaults, paralleling devices may be extremely difficult to use. It is possible to use an 8-inch FFD, and the objectionable, bulky, extension cylinder necessary in the paralleling technique can be avoided.

Shorter exposure times can be used in the bisecting technique because of the shorter FFD; hence there is less chance for patient movement.

Disadvantages

The bisecting technique is that the image projected on the film is dimensionally distorted.

The bisecting technique is difficult to perform with the patient in a contour chair or in the supine position and the occlusal plane of the jaw being radiographed is parallel to the floor. All vertical angulations used in the bisecting technique are measured from this line.

In the bisecting technique the radiopaque image of the zygomatic arch is often superimposed on the apices of the maxillary molars, making diagnosis difficult.

The use of an 8-inch FFD. The 8-inch FED when compared to the extended 16-inch FFD causes greater image enlargement and distortion. There is also more tissue volume exposed with an 8-inch FFD than with a 16-inch FFD.

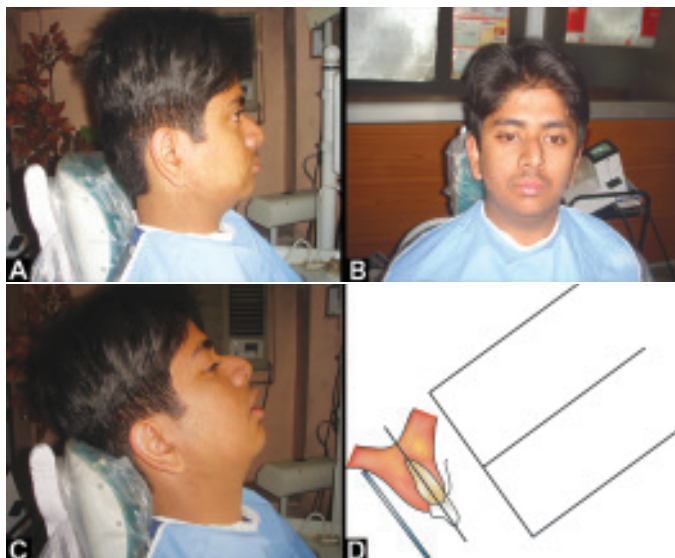
If the patient's finger is used to support the film, as is common in this method, then the patient's finger and hand are exposed unnecessarily to primary radiation. A bite block always should be used instead of the patient's finger.

Projection of the X-ray beam perpendicular to films that are placed parallel to the long axis of the teeth provides virtually correct orientation of all structures depicted.

Bisecting-angle Technique

For the maxillary regions the head should be positioned in the headrest, so that the plane of occlusion is parallel to the plane of the floor, and the sagittal plane is perpendicular to the plane of the floor. For the mandibular regions the head must be tilted directly backward to a position where the plane of occlusion is parallel to the plane of the floor when the mouth is opened sufficiently to accommodate the forefinger of the patient or a bite-block film holder (Figs 13.10A to D).

In the bisecting-angle technic the film is positioned in the mouth so as to contact the teeth and the soft tissues over their supporting structures. Although a film so positioned is close to the coronal portion of the tooth, it is at some



Figs 13.10A to D: (A) For maxillary teeth the plane of occlusion parallel to the plane of the floor. (B) Sagittal plane is perpendicular to the plane of floor. (C) Mandibular teeth, the plane of occlusion parallel to the plane of floor when the mouth is open. (D) The placement a film and direction of the PID

distance from the apices of the roots because of the curvature of the palate and muscles attached to the lingual surface of the mandible. The film and the long axis of the tooth then form an angle and an X-ray beam directed perpendicular to either the film or the long axis of the tooth will produce a markedly distorted image on the radiograph; To avoid distortions in the length of the image of the tooth, the bisecting-angle technic employs a geometric principle whereby the beam of radiation is directed at right angles to an imaginary line or plane which bisects the angle formed

by the film and the long axis of the tooth. Since the ray passes through the tooth obliquely, distortion of the image is not completely eliminated.

Positioning Techniques

The bisecting angle technique is performed either by using a film holder to support the film packet in the patient's mouth or by asking the patient to use gently index finger or thumb to support the film packet. The film holder is recommended to avoid irradiation to the patient's finger.

Bisecting Technique Using Film Holders

The Emminix film holder or the Rinn-Greene stable bite block is used to hold the film packet in the desired position.

1. The film packet is pushed securely into the chosen holder.
2. A large or small size film packet is used so that the particular tooth being examined is in the middle of the film.
3. The white surface of the film packet is placed facing the X-ray tube head with the dot opposite the crown.
4. X-ray tube head is positioned by assessing the vertical and horizontal angulations of the individual tooth.
5. The exposure is made.

Bisecting Technique Using Patient's Finger

1. Appropriate size film packet is selected. The film packet is positioned and orientated with about 2-3 mm extending beyond the incisal or occlusal edges, to ensure that all the length of the tooth will appear on the film.
2. Ask the patient to gently support the film packet using either an index finger or thumb.

3. The operator then assesses the vertical and horizontal angulations and then position the X-ray tube accordingly.
4. The exposure is made.

PARALLELING TECHNIQUE

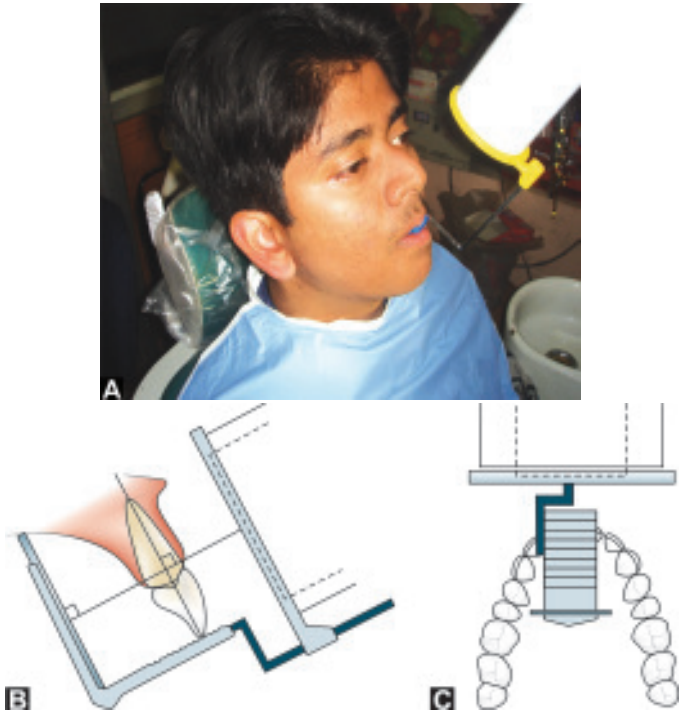
1. The film is assembled in the film holder according to the information given by the manufacturer.
2. Set the X-ray unit for exposure such as kilovoltage, milliamperage and time.
3. The film is placed in the film holder (size 1 film for the anterior exposure and size 2 film for posterior exposure). The film packet for anterior exposure is inserted vertically into the bite block and secured in the slot. For posterior exposure this is placed horizontally into the bite block and secured in the slot.

Maxillary Incisor Exposure

1. The chair is positioned so that maxillary occlusal plane is parallel the floor and the sagittal plane of the patient's face is perpendicular to the floor.
2. The film is placed vertically in the palate away from the lingual surfaces of the teeth and make sure that the long axis of the film packet is parallel to the long axis of the teeth.
3. Center of the film and film holder should be between the central incisor and the lateral incisor.
4. Instruct the patient to "slowly close" on the bite block.
5. Align the open face of the PID with the ring. The central ray is directed at the center of the film and expose the film (Figs 13.11A to C).

Maxillary Canine Exposure

1. Chair position is same as in maxillary incisor.
2. The film is placed vertically, away from the lingual surface of the canine and parallel to its long axis.

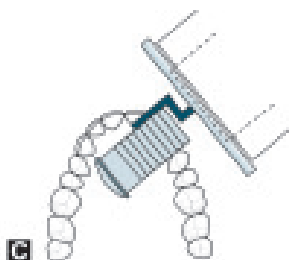
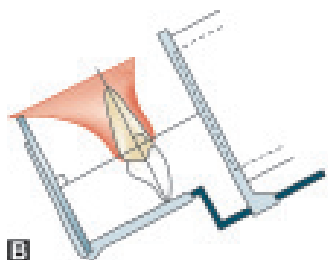


Figs 13.11A to C: Positioning of the patient, film and PID for maxillary incisors

3. Center of the film is behind the canine.
4. Align and the PID with the aiming ring and expose the film (Figs 13.12A to C).

Maxillary Premolars Exposure

1. The chair is positioned so that the maxillary occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.

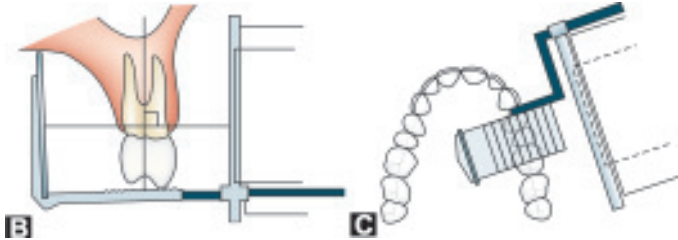


Figs 13.12A to C: Positioning of the patient, film and PID for maxillary canine

2. The center of the film aligns with the second premolar. The film is placed horizontally away from the lingual surfaces of the premolar so that its long axis is parallel to the long axis of the premolar.
3. The localizing ring is align in contact with the open-ended PID and expose the film (Figs 13.13 A to C).

Maxillary Molars Exposure

1. The chair is positioned so that the maxillary occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.

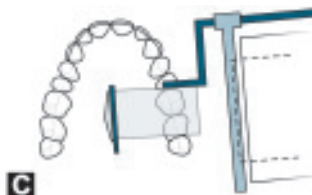
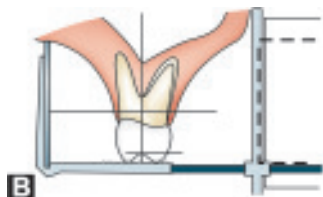
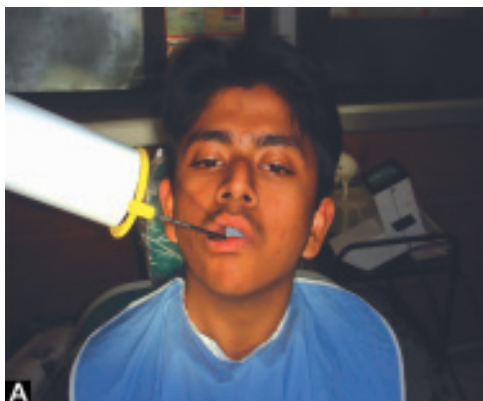


Figs 13.13A to C: Positioning of the patient, film and PID for maxillary premolars

2. The film is placed horizontally away from the lingual surfaces of the molars so that the long axis of the film lies parallel to the long axis of the molars. The center of the film packet aligns with the middle of the second molar
3. Align the PID with the localizing ring and expose the film (Figs 13.14A to C).

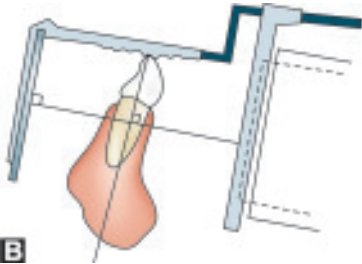
Mandibular Incisors Exposure

1. The patient is positioned on the chair so that when the mouth is open the mandibular occlusal plane should be parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.



Figs 13.14A to C: Positioning of the patient, film and PID tube for maxillary molars

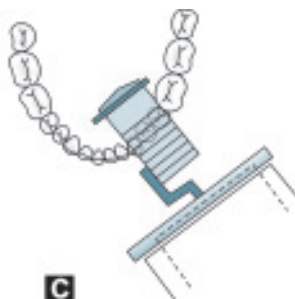
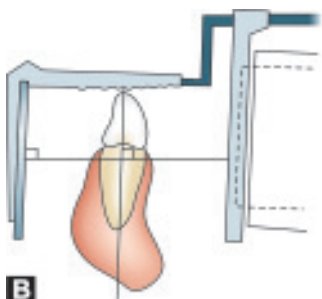
2. The film is placed vertically away from the lingual surfaces of the incisors so that the long axis of the film is parallel to the long axis of the incisors.
3. The film is centered at the midline so that all four incisors appear on the film.
4. Instruct the patient to 'slowly bite' on the bite block (Figs 13.15A to C)
5. Align the PID with the localizing ring and expose the film.



Figs 13.15A to C: Positioning of the patient, film and PID tube for maxillary incisors

Mandibular Canine Exposure

1. The patient is positioned on chair so that when the mouth is open the mandibular occlusal plane should be parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.
2. The film is placed vertically away from the lingual surface of the canine so that its long axis is parallel to that of canine.
3. The film packet is positioned so that the canine is in the center of the film.

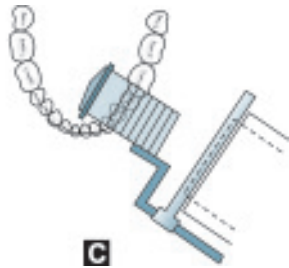
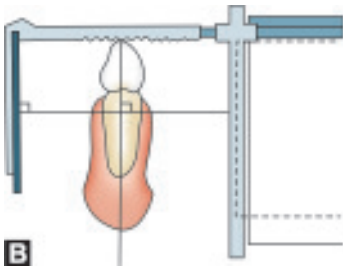


Figs 13.16A to C: Positioning of the patient, film and PID tube for mandibular canine

4. Instruct the patient to 'slowly bite' on the bite block.
5. Align the PID with the localizing ring and expose the film (Figs 13.16A to C).

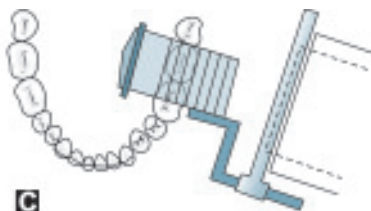
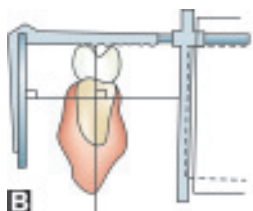
Mandibular Premolar Exposure

1. The patient is positioned on the chair so that when the mouth is open the mandibular occlusal plane parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.



Figs 13.17A to C: Positioning of the patient, film and PID tube for mandibular premolar

2. The film is placed so that the film is parallel to the long axis of the premolar. The second premolar is centered behind the film packet. The object film distance should be minimal and the film is positioned very close to the tooth.
3. Align the open ended PID with the localizing ring and expose the film (Figs 13.17A to C).



Figs 13.18A to C: Positioning of the patient, film and PID tube for mandibular molar

Mandibular Molars Exposure

1. The patient is positioned on the chair so that when the mouth is open the mandibular occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.
2. The film is placed lingually to the molar so that the long axis of the film is parallel to the long axis of the molars.
3. The central ray is directed at the center of the film.
4. Align the open ended PID with the localizing ring and expose the film (Figs 13.18A to C).

BISECTING TECHNIQUE

Procedure

In this technique, the film is placed as close to the tooth as possible without bending the film. The film is not parallel to the long axis of the tooth. An imaging bisector line is drawn to bisect the angle formed by the long axis of the tooth and film and the central ray is directed perpendicular to the imaginary bisector.

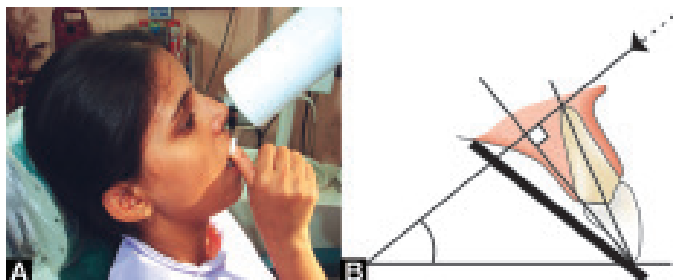
This gives the vertical angulation of the X-ray beam which is positive angulation for the maxillary teeth and negative angulation for the mandibular teeth. The PID is pointed down and up accordingly. The reference point for vertical angulation is zero-degree angulation when the PID is parallel to the floor.

Basic Rule for Bisecting Technique

1. The film must be placed and positioned against the lingual surface of the prescribed tooth. The upper end of the film must extend approximately 1/8 inch beyond the incisal or occlusal surface of the teeth.
2. The patient should be instructed to press the film gently against the middle of the film.
3. The central ray is directed perpendicular to the imaginary bisector which is a line bisecting the angle formed by the film and the long axis of the tooth.
4. The central ray of the X-ray beam is directed through the contact areas between the teeth.
5. The X-ray beam is directed at the center of the X-ray film.

Maxillary Central and Lateral Incisors

1. The chair is positioned so that the maxillary occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.



Figs 13.19A and B: (A) Patient position supporting the film with the thumb. (B) Diagram of the position of film, maxillary incisor and X-ray beam

2. The film packet is placed vertically so that the lower border extends $1/8$ inch below the incisal edge of the incisors. The film is held as close to the lingual surface of the incisors as possible without bending the film.
3. PID is angulated vertically +50 degrees.
4. The central ray is directed perpendicular to the film packet in the horizontal plane between the contacts of the incisors and the directed from below the tip of the nose.
5. Expose the film (Figs 13.19A and B).

Maxillary Canines

1. The patient is positioned so that the maxillary occlusal plane is positioned parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.
2. The film packet is held vertically so that the longer edge of the film parallel to the occlusal plane and $1/8$ inch extends below the tip of the canine. The canine is in the center of the film packet.
3. Instruct the patient to hold the film by light pressure using the thumb or index finger of the opposite hand of the side on which the film is placed.

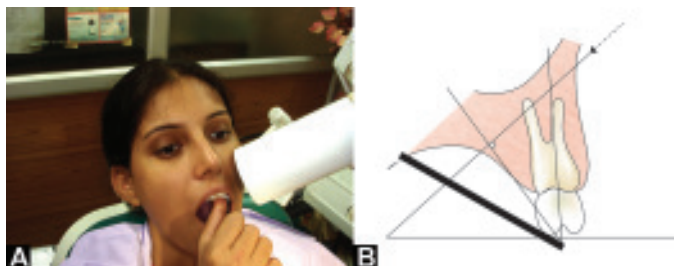


Figs 13.20A and B: (A) Patient position supporting the film with the thumb. (B) Diagram of the position of film, maxillary canine and X-ray beam

4. The central ray is directed at the base of the lateral nasal groove, perpendicular to the imaginary bisector between the contacts of the canine and first premolar.
5. PID is angulated vertically +50 degrees.
6. Expose the film (Figs 13.20A and B).

Maxillary Premolar

1. The patient is positioned on the chair so that the maxillary occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.
2. The film packet is held horizontally parallel to the occlusal plane so that 1/8 inch extends below the occlusal edges of the teeth.
3. Instruct the patient to hold the film with light pressure by the thumb or index finger. The second premolar is in the center of the film packet.
4. The central ray is directed at the most anterior part of the cheek bone, at the center of the film packet between the contacts of the premolars.
5. PID is directed at +40 degree vertical angulation.
6. Expose the film (Figs 13.21A and B).



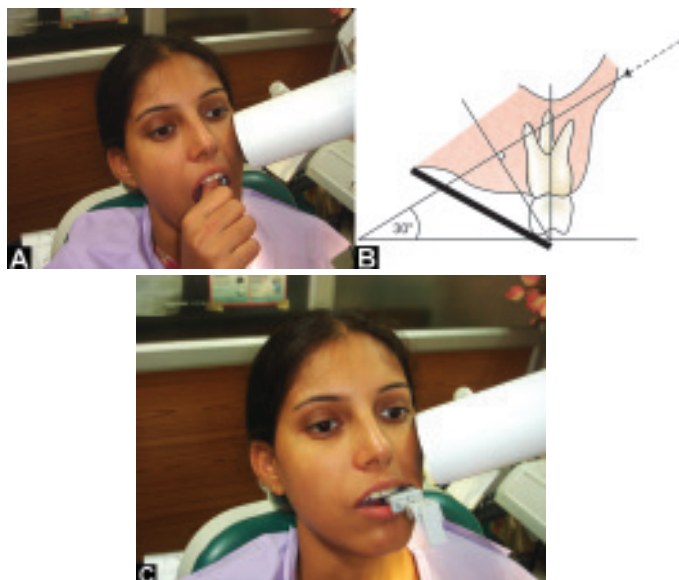
Figs 13.21A and B: (A) Patient position supporting the film with the thumb. (B) Diagram of the position of film, maxillary premolar and X-ray beam

Maxillary Molars

1. The patient is positioned on the chair so that the maxillary occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.
2. The film packet is held horizontally parallel to the occlusal plane so that 1/8 inch extends below the occlusal surfaces of the teeth. The second molar is in the center of the film packet.
3. Instruct the patient to hold the film using the thumb or index finger and exerts light and firm pressure on the film.
4. The central ray is directed through the zygomatic arch at the center of the film between the contacts of the molars. The distal curvature of the open ended cone should not be distal to the outer canthus of the eye.
5. PID is angulated +30 degrees vertically.
6. Expose the film (Figs 13.22A to C).

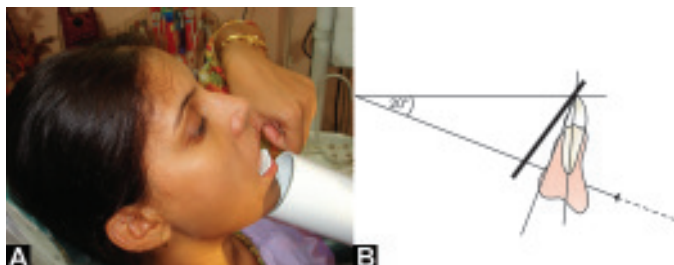
Mandibular Incisor

1. The patient is positioned on the chair so that when the mouth is open the mandibular occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.

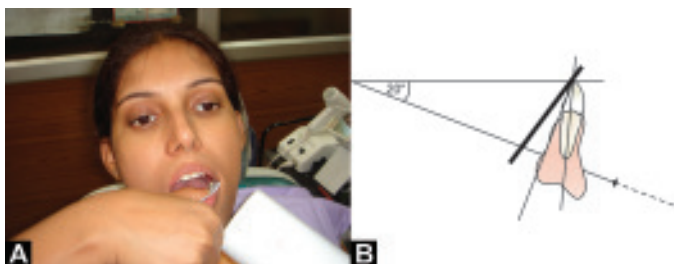


Figs 13.22A to C: (A) Patient position supporting the film with the thumb. (B) Diagram of the position of film, maxillary molar and X-ray beam. (C) Film is in the holder

2. The film packet is held vertically so that it extends 1/8 inch above the incisal edges of the incisors. All the four lower incisors are shown on the film.
3. Instruct the patient to hold the film with light firm pressure on the lingual surfaces of the incisors.
4. The central ray is directed at the depression on the face just above the chin between the contacts of the central incisors.
5. PID is angulated – 20 degrees vertically.
6. Expose the film (Figs 13.23A and B).



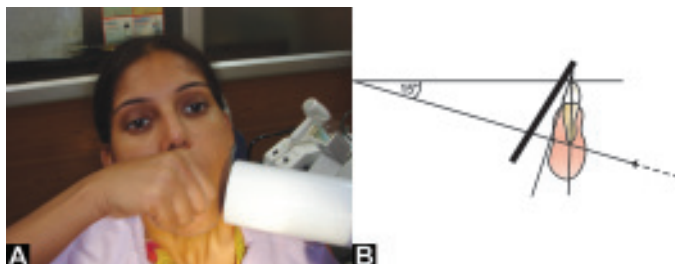
Figs 13.23A and B: (A) Patient position supporting the film with the thumb. (B) Diagram of the position of film, mandibular incisor canine and X-ray beam



Figs 13.24A and B: (A) Patient position supporting the film with the thumb. (B) Diagram of the position of film, mandibular canine and X-ray beam

Mandibular Canine

1. The patient is positioned on the chair so that when the mouth is open the mandibular occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.
2. The film packet is held vertically so that it extends 1/8 inch above the tip of the canine.
3. Instruct the patient to hold the film with light firm pressure on the lingual surface of the canine.



Figs 13.25A and B: (A) Patient position supporting the film with the thumb. (B) Diagram of the position of film, mandibular premolar and X-ray beam

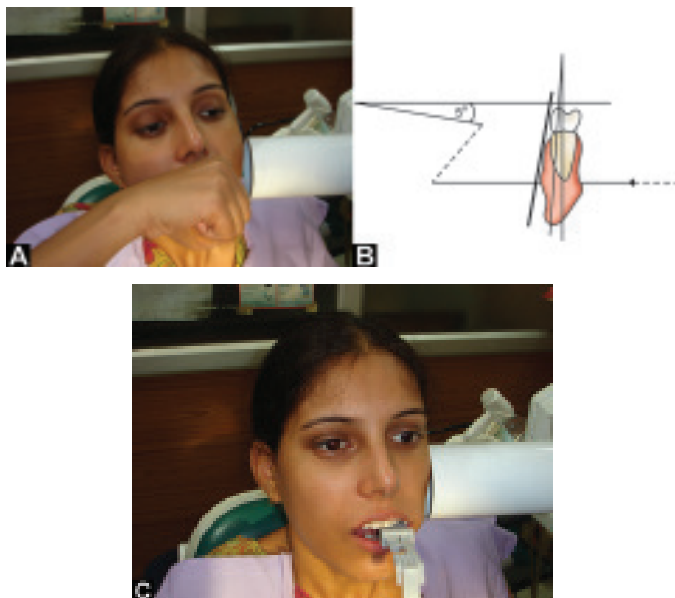
4. The central ray is directed at the root of the canine, between the contacts of the canine and first premolars.
5. PID is angulated – 20 degrees vertically.
6. Expose the film (Figs 13.24A and B).

Mandibular Premolar

1. The patient is positioned on the chair so that when the mouth is open the mandibular occlusal plane is parallel to the floor, and the sagittal plane of the patient's face is perpendicular to the floor.
2. The film packet is held horizontally so that it extends 1/8 inch above the occlusal surfaces of the teeth.
3. Instruct the patient to hold the film with light, firm pressure against the lingual surfaces of the teeth.
4. The central ray is directed at the mental foramen between the contacts of the premolars.
5. PID is angulated – 15 degrees vertically.
6. Expose the film (Figs 13.25A and B).

Mandibular Molars

1. The patient is positioned on the chair so that when the mouth is open the mandibular occlusal plane is parallel to the floor and the sagittal plane of the patient's face is perpendicular to the floor.



Figs 13.26A to C: (A) Patient position supporting the film with the thumb. (B) Diagram of the position of film, mandibular molar and X-ray beam. (C) Film is in the holder

2. The film packet is held horizontally so that it extends 1/8 inch above the occlusal surfaces of the molars, the second molar is in the middle of the film.
3. The film is held with light firm pressure against the lingual surface of the molars. Because of the anatomy in the area of the molars, the film is almost parallel to the long axis of the tooth and most molar periapical film done in the bisecting technique are really parallel films.
4. The center ray is directed at the roots of the molars between the contacts of the molars.
5. PID is angulated – 5 degrees vertically.
6. Expose the film (Figs 13.26A to C).

Chapter 14

Bitewing and Occlusal Radiography

BITEWING RADIOGRAPHY

Bitewing radiography is the technique in which the patient is required to bite on a small wing attached to an intraoral film packet (Fig. 14.1). Modern film holders now have eliminated the need for the wing (now termed a tab).

A bitewing radiograph is used to examine the interproximal surfaces of teeth; crestal bone.

Indications

- Detection of interproximal caries especially in detecting early carious lesions that are not evident clinically.
- Monitoring the progression of dental caries.
- Assessment of existing restorations.
- Assessment of the periodontal status, especially in examination of the crestal bone levels between teeth

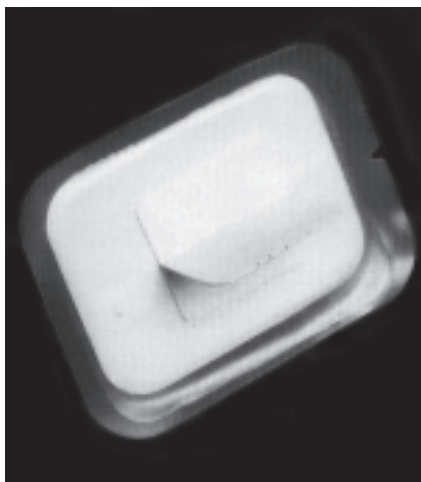
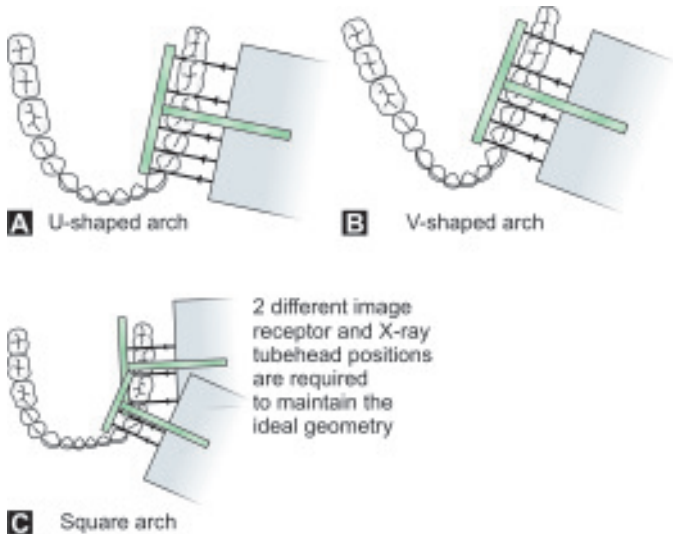


Fig. 14.1: Bitewing barrier wrapped film pack with tab

Principles

The basic principles of the bitewing technique is as follows:

- The film is placed in the mouth parallel to the crowns of both the upper and the lower teeth.
- The posterior teeth and the film packet should be in contact or as close together as possible.
- The posterior teeth and the film packet should be parallel for premolars and molars. Two separate film positions are required according to the shape of the dental arch (Figs 14.2A to C).
- The film packet should be positioned with its long axis horizontally for a horizontal bitewing or vertically for a vertical bitewing.



Figs 14.2A to C: For different arch shape, the different ideal image receptor and X-ray tubehead positions

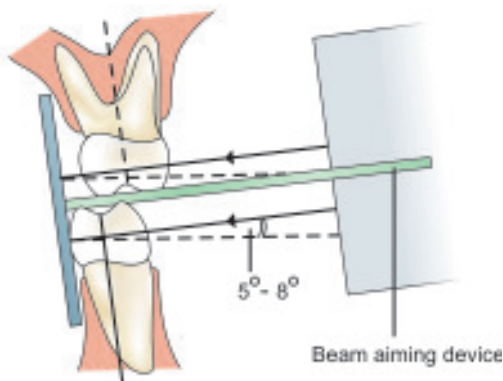


Fig. 14.3: Diagram showing 5°-8° downward vertical angulation of the X-ray beam compensating for the curve of Monson

- In the horizontal plane, the X-ray beam is directed to meet the teeth and the film packet at right angles and passes through all the contact areas of teeth.
- In the vertical plane, the X-ray beam should be directed downward (approximately 5°-8° to the horizontal) to compensate for the upwardly rising curve of Monson (Fig. 14.3).

BITEWING TECHNIQUES

There are two main techniques:

- Bitewing tab using a tab attached to the film packet.
- Film holder—using a film packet holder with beam aiming device.

Bitewing Tab

A bitewing film is a periapical film that has been fitted with a tab, the periapical film is oriented in the bite loop so that the tab portion extends from the white side (tube side) of the film.

Technique

1. Approximate size film is selected with a tab attached to it. Large film packets (31×41 mm) for adults and small film, packets (22×35 mm) for children under 12 years.
2. The patient is positioned with the occlusal plane horizontal and the head supported by head rest.
3. The operator holds the tab between thumb and forefinger and places the film packet into the lingual sulcus opposite the teeth.
4. The tab is placed on to the occlusal surfaces of the lower teeth and ask the patient to close the teeth firmly together on to the tab.
5. The operator pulls the tab firmly between the teeth to ensure that the film packet and teeth are in contact.
6. The operator releases the tab.
7. The X-ray beam is focused though the contact areas at right angles to the teeth and the film with an approximately 5° - 8° downward vertical angulation.
8. The film is exposed.

Using Bitewing Film Holder

The film holder is a device used to position an intraoral film in the mouth and retain the film in position during the exposure. Film holders eliminate the need for the patient to stabilize the film.

Different design of film holders are available for bitewing film such as Rinn XCP bitewing holder, Hawe-Neos Kwikbite.

It consists of three basic components:

- A mechanism for holding the film packet parallel to the teeth.
- A bite-plate form that replaces the wing.
- An X-ray beam aiming device.

This has the advantage over bitewing tab that:

- The film packet is held firmly in position and cannot be displaced by the tongue.
- Position of X-ray tubehead is determined by the holder thus arbitrary, horizontal and vertical angulations of the X-ray tubehead is not present and the X-ray beam is always at right angles to the film packet.
- The cone cutting of anterior part of the film avoided.

Film Size

Four sizes of bitewing film (0, 1, 2 and 3) are available (Fig. 14.4):

- Size 0:** This is used to examine the posterior teeth of children with primary dentitions.
- Size 1:** This film is used to examine the posterior teeth of children with mixed dentitions and also to examine anterior teeth of adults.
- Size 2:** This film is used to examine the posterior teeth in adults and may be placed horizontally or vertically.
- Size 3:** Film is longer and narrower than the standard size 2 film and is used only for bitewings to examine all the premolar and molar contact areas. Usually size 2 film is used for bitewing exposures in adult patient.

Exposure Factors for Bitewings

The exposure factors should be determined for two clinical reasons.

- Assessment of caries and restorations.
- Assessment of periodontal status.

For assessment of caries, the film should be well-exposed and show good contrast to differentiate between enamel and dentine and also dentinoenamel junction.

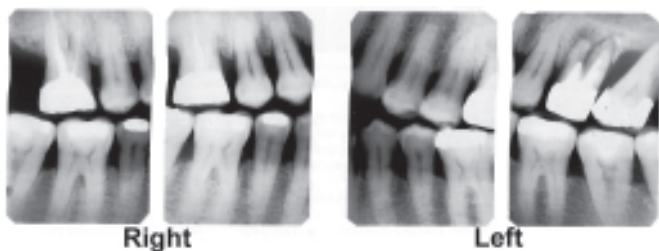


Fig. 14.4: Showing example of typical RIGHT and LEFT vertical adult bitewing radiographs. Note that two films are used on each side to image both the premolars and molars

For assessment of periodontal status the films should be under exposed to avoid burn out of the thin alveolar crestal bone.

OCCLUSAL RADIOGRAPHY

Occlusal radiography is an intraoral technique where size 4 intraoral film (57×76 mm) is placed in the occlusal plane.

Indications

- To locate supernumery, unerupted canines, impacted teeth and odontomas.
- For determining the bucco/palatal position of unerupted canines.
- Evaluation of the size and extent of lesions, such as, cysts or tumors in the anterior maxilla.
- To locate foreign body in the maxilla or mandible.
- To locate salivary stones in the duct of the submandibular gland.
- Assessment of fractures of the maxilla or mandible.
- To examine the area of a cleft palate, assessment of bucco-lingual expansion of cortical plates due to a cyst or tumor in maxilla or mandible.

- To locate retained root or displaced roots in the maxillary sinus.
- To evaluate the boundaries of the maxillary sinus.

Principles

The basic principles of the occlusal technique are as follows:

- The film is placed with the white side facing the arch (mandibular or maxillary) that is being exposed.
- The film is placed in the mouth between the occlusal surfaces of the maxillary and the mandibular teeth.
- The patient gently bite the film for stabilization.

TECHNIQUES IN OCCLUSAL RADIOGRAPHY

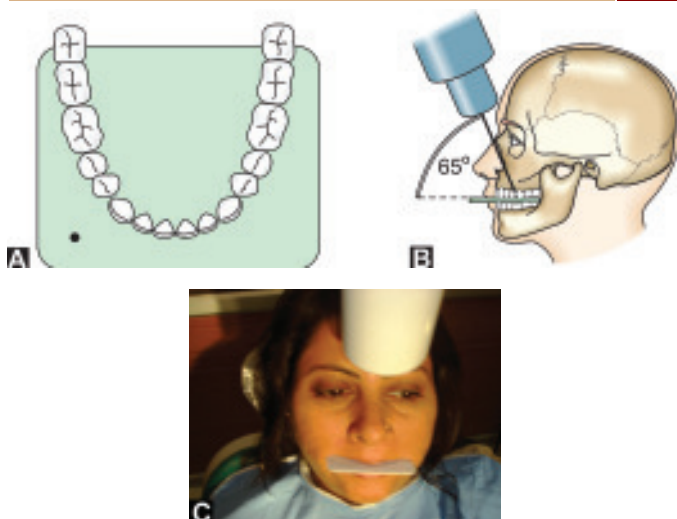
Maxillary Standard Occlusal

Indications are to detect the presence of unerupted canines, supernumeraries, odontomas, assessment of fractures in the anterior teeth and alveolar bone, determination of buccopalatal position of unerupted canines.

Technique

The patients are seated with the head supported and the occlusal plane horizontal and parallel to the floor.

- The film packet with the white surface facing uppermost is placed into the mouth on to the occlusal surfaces of the lower teeth. The patient is asked to bite gently on to the film. The film packet should be placed centrally in the mouth with its long axis crossways in adults and anteroposteriorly in children.
- The X-ray tubehead is focused above the patient in the midline aiming downward through the bridge of the nose at an angle of 65° - 70° to the film packet (Figs 14.5A to C).



Figs 14.5A to C: (A) Showing the film position in relation to the arch. (B) Position of the X-ray tube. (C) Position of the patient

Maxillary Oblique Occlusal

This is used for determining the position of roots displaced in advertently into the antrum during attempted extraction of upper posterior teeth and fracture of the posterior alveolar bone.

Technique

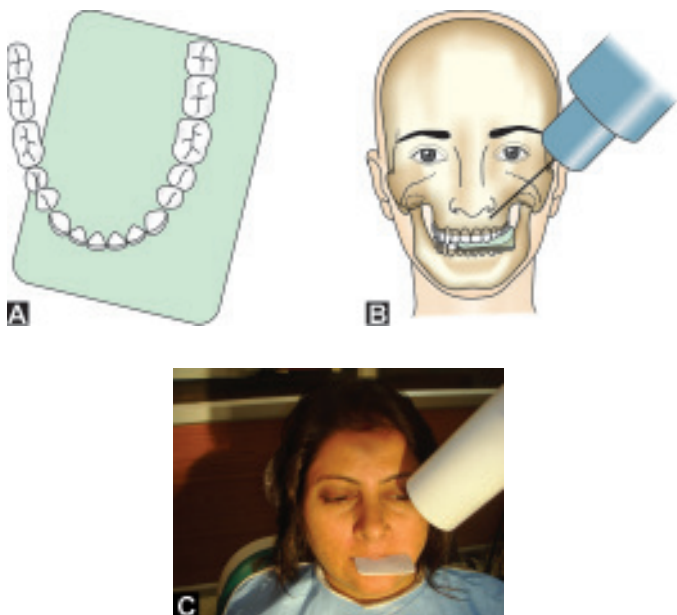
The patient is seated with the head supported and occlusal plane is horizontal and parallel to the floor.

- The film packet with the white surface facing uppermost is placed on to the occlusal surfaces of the lower teeth with its long axis anteroposteriorly.
- Ask the patient to bite gently.

- The X-ray tubehead is positioned to the side of the patient's face aiming downward through the cheek at an angle of 65° - 70° to the film centring on the region of interest (Figs 14.6A to C).

Vertex Occlusal

This view shows the tooth bearing portion of the maxilla from above. An excessive amount of radiation dose is required to pass through a considerable amount of tissue. To avoid this an intensifying screen with intraoral cassette is used to reduce the dose of radiation. The central ray is



Figs 14.6A to C: (A) Showing position of the film in relation to the lower arch. (B) Position of the tube from the front. (C) Position of the patient

directed at 90 degrees to the film packet. Now this view is no longer used commonly.

Technique

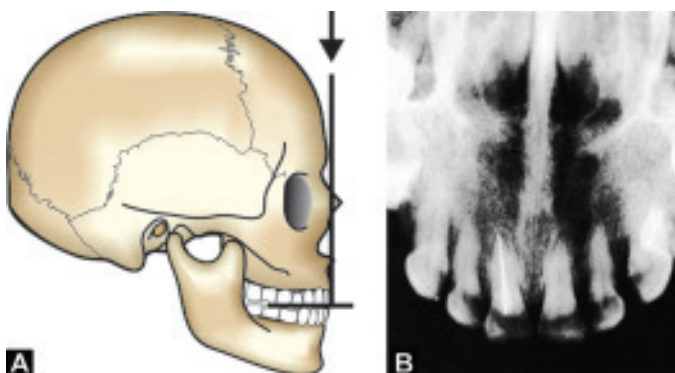
- The patients head is supported and the occlusal plane should be horizontal and parallel to the floor.
- The cassette is placed inside a small plastic bag to prevent salivary contamination and cross infection.
- The cassette is placed in the mouth on to the occlusal surfaces of the lower teeth with its long axis anteroposteriorly and patient bites on it.
- The X-ray tube is positioned above the patient in the midline aiming downward through the vertex of the skull. The X-ray beam is directed downward along the long axis of the root canals of the upper incisor teeth (Figs 14.7A and B).

Mandibular 90° Occlusal

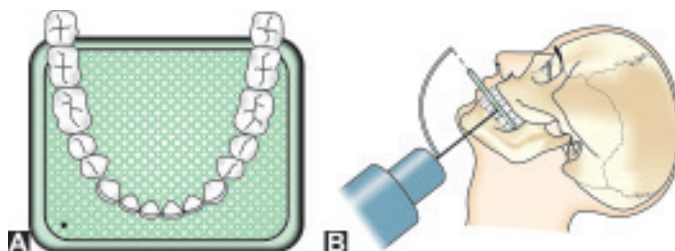
This view shows the tooth bearing portion of the mandible and the floor of the mouth. This is indicated for detection of calculi in the submandibular salivary ducts, buccolingual expansion of the body of the mandible by cyst or tumor and displaced fractures of the anterior portion of the mandible symphysis and parasymphysis areas.

Technique

- The film packet with the white surface facing downward, is placed centrally into the mouth, on to the occlusal surfaces of the lower teeth and ask the patient to bite gently.
- The patient head is positioned backward as far as is comfortable and supported by the head rest.
- The X-ray tubehead with the circular collimator fitted is placed below the patients chin, in the midline, with the center of focus in the middle of the imaginary line joining the first molars, at an angle of 90° to the film (Figs 14.8A to C).



Figs 14.7A and B: (A) Showing the position of the film head.
(B) Showing the occlusal photo view of anterior maxilla



Figs 14.8A to C: (A) Showing the position of the film in relation to the lower arch. (B) Position of the tube. (C) Position of the patient

For visualizing this X-ray, the embossed dot should be pointed away from the examiner because the film is placed 90° occlusal and it looks like as if the examiner is looking into the patients mouth.

Lower 45° Occlusal

This view is used to show the lower anterior teeth and the anterior part of the mandible. This technique is just like the periapical bisecting technique.

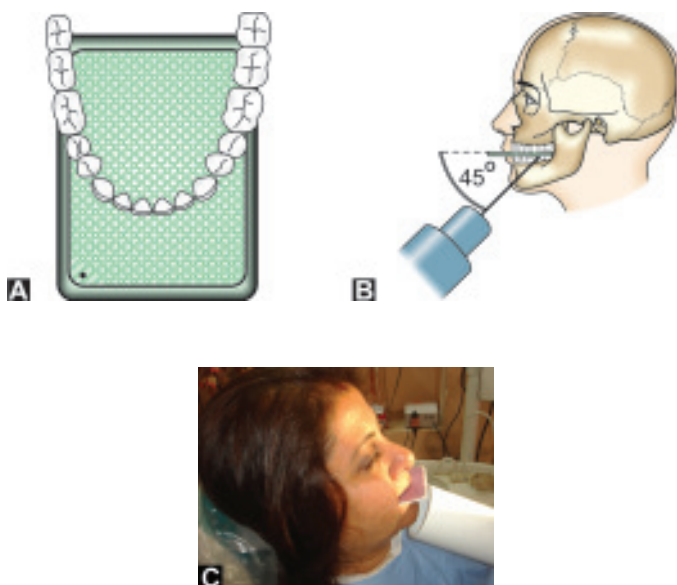
This technique is indicated to assess the lower anterior teeth, extent and size of cysts or tumors in the anterior part of the mandible and assessment of displaced anterior mandibular fracture.

Technique

- The patient is seated with the head supported and the occlusal plane, horizontal and parallel to the floor.
- The film packet with white surface facing downward, is placed centrally into the mouth, on to the occlusal surface of the lower teeth, with its long axis anteroposteriorly and ask the patient to bite gently.
- The X-ray tubehead is positioned in the midline at an angle of 45° to the film centering through the chin (Figs 14.9A to C).

Lower Oblique Occlusal

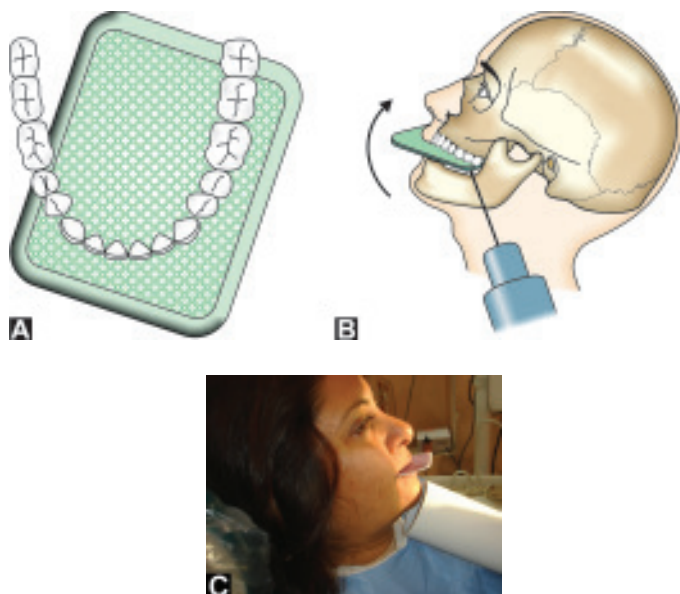
This view is useful to visualize radiopaque calculi in the posterior part of the submandibular gland, on the side of interests. The indications for this technique are detection of radiopaque calculi in the submandibular salivary gland, assessment of buccolingual position of mandibular third molar teeth and evaluation of the extent and expansion of the cortical plates by cysts or tumors.



Figs 14.9A to C: (A) Showing the occlusal view of anterior maxilla. (B) Position of the tube. (C) Position of the patient

Technique

- The patient's head is supported and rotated away from the side under investigation and the chin raised.
- The film packet with the white surface facing downward, is placed on to the occlusal surfaces of the teeth, over the side under investigation with its long axis anteroposteriorly.
- Ask the patient to bite gently.
- The X-ray tubehead with circular collimator is placed upward and forward toward the film from below and



Figs 14.10A to C: (A) Showing position of the film in relation to the lower arch. (B) Position of tube from the side. (C) Position of the patient

behind the angle of the mandible and parallel to the lingual surface of the mandible (Figs 14.10A to C).

To visualize the X-ray, the embossed dot should be pointed away from the examiner.

Chapter 15

Panoramic Radiography (Pantomography)

PANORAMIC RADIOGRAPHY

Panoramic radiography is like all other forms of tomography in which the resultant film is a sectional radiograph, only structures within the focus on the film will be visible. The focal or section through the structure is designed to be approximately horseshoe shaped, corresponding to the shape of dental arches. The image quality in panoramic radiograph is inferior to that of intraoral periapical radiograph. But still this has become a very popular radiographic technique in dentistry. The main advantages of the technique are:

- All the teeth and supporting structures of upper and lower arches are shown on one film.
- The technique is simple.
- Less amount of radiation dose is required. The dose is equivalent to about three or four periapical radiographs.

Basic Concepts

A panoramic film shows a wide view of the upper and lower jaws. Panoramic radiography is an extraoral radiographic technique that is used to examine the upper and lower jaws on a single film. An extraoral film is one that is positioned outside the mouth during X-ray exposure. In panoramic radiography (also known as rotational panoramic radiography), both the film and the tubehead rotate around the patient, producing a series of individual images. When such images are combined on a single film, an overall view of the maxilla and mandible is created.

Fundamentals

The X-ray tube rotates around the patient's head in one direction while the film rotates in the opposite direction. The

patient may stand or sit in a stationary machine that is used. The movement of the film and the tubehead produces an image through the process known as tomography. The term tomo means section. Tomography is a radiographic technique that allows the imaging of one layer or section of the body while blurring images from structures in other planes. In panoramic radiography, this image conforms to the shape of the arches.

Uses

- To locate impacted teeth, especially impaction of mandibular third molar in ramus area and maxillary canine high up near the floor of orbit.
- To evaluate eruption patterns, growth, and development.
- To detect diseases (especially in the mixed dentition), lesions and conditions of the jaws.
- To examine the extent of large lesions.
- To evaluate trauma.

The images on a panoramic film are not as defined or sharp as the images seen on intraoral films. Consequently, a panoramic film should not be used to evaluate and diagnose caries, periodontal disease or periapical lesions. The panoramic radiograph should not be used as a substitute for intraoral films.

Basis of Panoramic Radiography

The difficulty in panoramic tomography arises from the need to produce a final shape of focal trough, which approximates to the shape of the dental arches. The different shapes of focal trough to achieve final horseshoe shape include:

- Linear tomography using a wide or broad X-ray beam.
- Linear tomography using a narrow or slit X-ray beam.
- Rotational tomography using a slit X-ray beam.

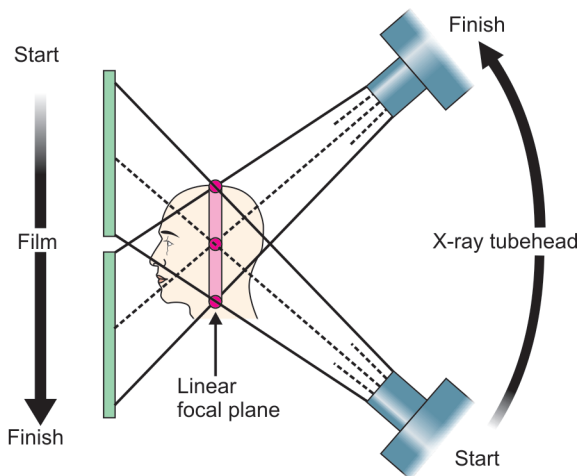


Fig. 15.1: Diagram showing the synchronized movement of the X-ray tubehead and the film in broad beam linear tomography which exposes the entire film throughout the exposure

1. **Broad beam linear tomography:** The synchronized movement of the tubehead and film, in the vertical plane, results in a straight linear focal trough. The broad X-ray beam exposes the entire film throughout the exposure (Fig. 15.1).
2. **Linear tomography using a narrow or slit beam:** A straight linear tomography can also be achieved by using a narrow or slit X-ray beam. The equipment is modified and designed in such a way that a narrow beam traverses the film (Fig. 15.2). With the tomographic movement the entire film has been exposed. The modifications in the equipment are:
 - The X-ray beam has to be collimated from a broad beam to a narrow beam.

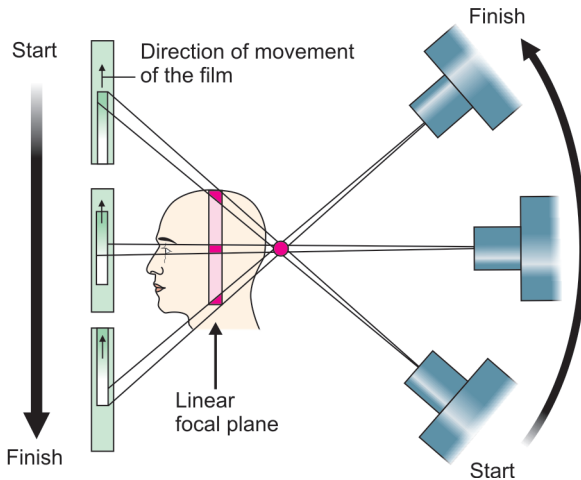


Fig. 15.2: Diagram showing the synchronized movement of the X-ray tubehead and the cassette carrier in narrow-beam linear tomography which exposes different part of the film throughout the cycle

- The film cassette has to be placed behind a protective metal shield, which has a narrow opening to allow a small part of the film to be exposed by X-ray beam.
- To produce synchronized tomographic movement in the vertical plane, a cassette carrier is used which is incorporating the metal shield to be linked to the X-ray tubehead to move in opposite direction to one another during the exposure.
- The film cassette within the carrier has to move in the same direction as the tubehead so that the different part of the film is exposed to the X-ray beam throughout the exposure.

Rotational Tomography with a Narrow Beam

A narrow beam equipment is used and the synchronized movement of the X-ray tubehead and the cassette carrier are designed to rotate in the horizontal plane, in a circular path around the head, with a single center of rotation. The resulted focal trough is curved and forms the arc of a circle (Fig. 15.3).

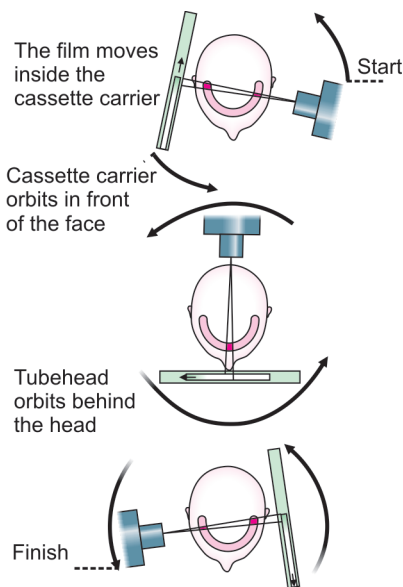


Fig. 15.3: Diagram showing the synchronized movement of the X-ray tubehead and the cassette carrier in narrow-beam rotational tomography which exposes different parts throughout the cycle

Dental Panoramic Tomography

The maxillary and mandibular arches, though curved is not the shape of an arc of a circle. The principle of narrow beam rotational tomography using two or more centers of rotation are used to produce an elliptical, horseshoe shaped focal trough (Fig. 15.4).

The different dental panoramic units are available which work on the same principle but differ in the rotational

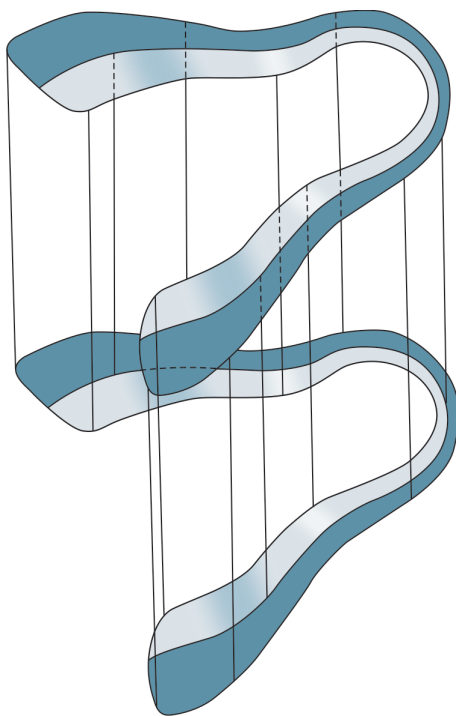


Fig. 15.4: Image layer or focal trough

movement to image the elliptical dental arch. There are four main methods which are:

- a. Two stationary center of rotation, using two separate circular areas.
- b. Three stationary center of rotation, using three separate circular arcs.
- c. A continually moving center of rotation using multiple circular arches.
- d. A combination of three stationary centers of rotation and a moving center of rotation.

The focal troughs are produced which are three dimensional and thus described as a focal corridor. In the final radiograph, all structures within the corridor including mandibular and maxillary teeth will be in focus.

Rotation Center

In panoramic radiography, the film or cassette carrier and X-ray tubehead are connected and rotate simultaneously around a patient during exposure. The pivotal point, or axis, around which the cassette carrier and X-ray tubehead rotate is termed a rotation center. Depending on the manufacturer, the number and location of the rotational centers differ. One of the following three basic rotation centers which is used in panoramic X-ray machines are:

- The double center rotation.
- The triple center rotation.
- The moving center rotation.

In all the cases, the center of rotation changes as the film and tubehead rotate around the patient. This rotational change allows the image layer to conform the elliptical shape of the dental arches. The location and number of rotational centers influence the size and shape of the focal trough.

EQUIPMENT

In panoramic radiography, the use of special equipment including a panoramic X-ray unit, screen, film, intensifying screens and cassette is necessary.

PANORAMIC X-RAY UNITS

A number of different panoramic X-ray units are available. Panoramic units may differ in the number of the rotation centers, the size and shape of the focal trough, and the type of film transport mechanism used. The main components of the panoramic unit include (Fig. 15.5):

- X-ray tubehead
- Head positioner
- Exposure controls

The panoramic X-ray tubehead is very similar to an intraoral X-ray tubehead. The collimator used in the panoramic X-ray tubehead, however, differs from the collimator used in the intraoral X-ray tubehead. The collimator used in the panoramic X-ray machine is a lead plate with an opening in the shape of a narrow vertical slit.

The X-ray beam emerges from the panoramic tubehead, through the collimator is a narrow band.

The narrow X-ray beam that emerges from the collimator minimizes patient exposure to X-radiation.

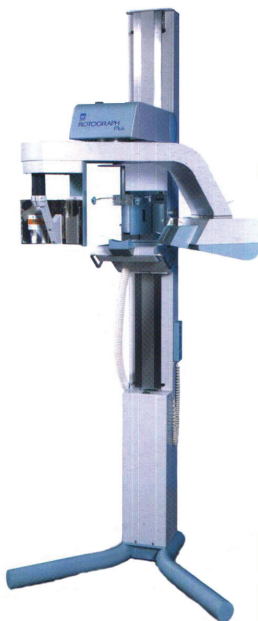


Fig. 15.5: Panoramic X-ray unit

A head positioner used to align the patient's teeth as accurately as possible in the focal trough. The typical head positioner consists of a chin rest, notched bite block, forehead rest and lateral head supports of guides.

Exposure factors (milliamperage and kilovoltage) are provided by the manufacturer in the X-ray machine instruction manual. The milliamperage and kilovoltage settings are adjustable and can be varied to accommodate patients of different sizes. The exposure time, however, is fixed and cannot be changed.

FILM

Screen film is used in panoramic radiography, this film is sensitive to the light emitted from intensifying screens. A screen film is placed between two intensifying screens in a cassette holder. When the cassette holder is exposed to X-rays, the screens convert the X-ray energy into light, which in turn exposes the screen film. The film used in panoramic radiography is available in two sizes 5 × 12 inch and 6 × 12 inch (Fig. 15.6).

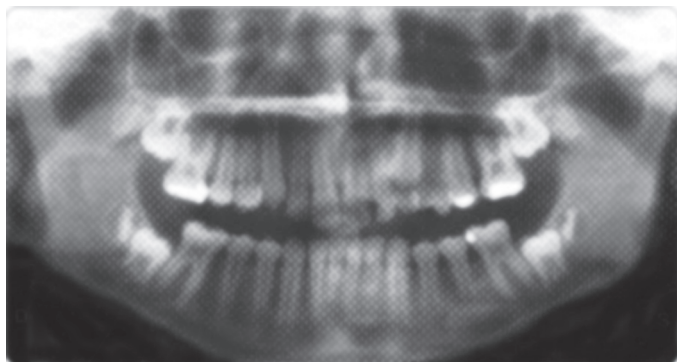


Fig. 15.6: Panoramic film

Intensifying Screens

There are two basic types of intensifying screens: calcium tungstate and rare earth. Calcium tungstate screens emit blue light, and the rare earth screens emit green light. Rare earth screens require less X-ray exposure than calcium tungstate screens and are considered "faster".

Cassette

The cassette is a device that is used to hold the extraoral film and intensifying screens. The cassette may be rigid or flexible curved or straight, depending on the panoramic X-ray unit. All cassettes must be light-tight to protect the film from exposure. One intensifying screen is placed on each side of the film and held in place when the cassette is closed.

The cassette must be marked to orient the finished radiograph. Prior to exposure, a metal letter R can be attached to the front of the cassette to indicate the patient's right side; the letter L is used to identify the patient's left side.

Procedure for Taking Panoramic Radiograph

1. Instruct the patient to sit or stand "as tall as possible" with the back straight and erect. The vertebral column is very dense; if the spine is not straight, a white shadow appears over the middle of the radiograph and obscures diagnostic information.
2. Instruct the patient to bite on the plastic bite block. The upper and lower front teeth must be placed in an end-to-end position in the groove (notch) that is found on the bite block. This groove is used to align the teeth in the focal trough. In edentulous patient the radiographer must align the upper and lower ridges over the notched area on the bite block.

3. Position the midsagittal plane (an imaginary line that divides the patient's face into right and left sides) perpendicular to the floor. The patient's head must not be tipped or tilted; if the midsagittal plane is not positioned perpendicular to the floor, a distorted image results on the panoramic radiograph, must have a high upper and lower ridges over the notched area on the bite block. Cotton rolls can be placed on each side of the bite block to provide stabilization for the patient
4. Position the Frankfort plane (an imaginary plane that passes through the top of the ear canal and the bottom of the eye socket) parallel with the floor. When the Frankfort plane is parallel to the floor, the occlusal plane is positioned at the correct angle.
5. Instruct the patient to position the tongue on the roof of the mouth. The radiographer may suggest that the patient "swallow" and feel the tongue rise up to the roof of the mouth and then instruct the patient to keep the tongue in the position during the exposure of the film. Also instruct the patient to close the lips around the bite block.
6. After the patient has been positioned instruct the patient to remain still while the machine is rotating during exposure.
7. Expose the film and proceed with film processing.

Errors

Proper patient preparation is critical in obtaining a diagnostic panoramic film. Two of the more common patient preparation errors including ghost images and the lead apron artifact. The patient positioning errors are—improper positioning of the lips and length and teeth. Improving positioning of the Frankfort plane and midsagittal plane and improper positioning of spine.

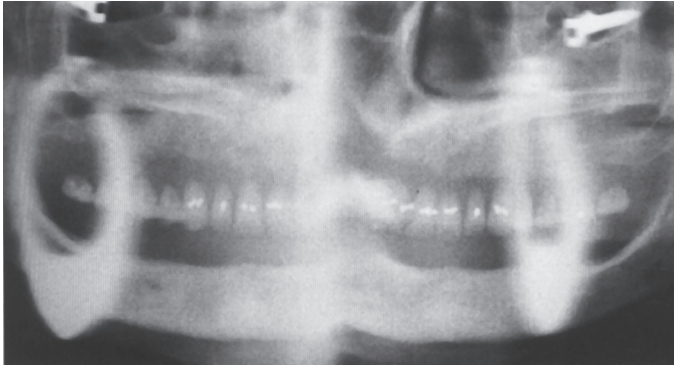


Fig. 15.7: The shadows of ear rings, maxillary denture and eye glasses from patient's face appear as Ghost image

GHOST IMAGES

A ghost image is a radiopaque artifact seen on a panoramic film that is produced when a radiodense object is penetrated twice by the X-ray beam (Fig. 15.7).

Problem

If all metallic or radiodense objects (e.g. eyeglasses, earrings, necklaces, hairpins, removable partial dentures, complete dentures, orthodontic retainers, hearing aids and napkin chains) are not removed before the exposure of a panoramic film, a ghost image results that obscures diagnostic information.

LEAD APRON ARTIFACT

Problem

If the lead apron is incorrectly placed or if a lead apron with a thyroid collar is used during the exposure of a panoramic



Fig. 15.8: Shadow of lead apron placed too high on the patient's neck

film, a radiopaque cone-shaped artifact results that obscures diagnostic information (Fig. 15.8).

To prevent such an artifact, the dental radiographer must always use a lead apron without a thyroid collar when exposing a panoramic film.

AN INTERPRETATION OF ANATOMIC STRUCTURES ON THE PANORAMIC IMAGE

Mandible

The major anatomic areas of mandible are:

- Condyle and temporomandibular joint.
- Coronoid process.
- Ramus.
- Body and angle.
- Symphysis and parasymphysis region.
- Teeth and supporting structures.

To visualize the mandible follow the cortical border on the outer and lower border without considering the dentitions

area. The border should be smooth without any interrupts (step deformities) or break in continuity and have symmetrical thickness and compare it with the other side especially in the angles, inferior border and posterior border of ramus.

Examine the TMJ gross anatomic curves of the condylar head and glenoid fossa. The condyle is generally positioned slightly anteroinferior to its normal closed position as the patient has to slightly open and protrude the mandible during the procedure of taking panoramic radiograph. Fracture can be visualized by a discontinuity (step deformity) with inferior border with change in the level of occlusal plane.

For any expansible lesion such as cyst or ameloblastoma the bone may be thinned. This is also seen in systemic diseases such as hyperparathyroidism and osteoporosis. Facial asymmetry may result because of conditions such as hemifacial hyperplasia or hypertrophy of coronoid process. The hyoid bone may be visualized below or onto the inferior border of the mandible.

A radiolucent shadow in panoramic radiograph is present in the molar area near the lower border of mandible. These are the depressions on the lingual surfaces of the mandible which are occupied by the submandibular and sublingual glands, known as lingual salivary gland fossae or depression (Fig. 15.9).

Midfacial Region

Midfacial region is complex structure of bone consisting of maxilla as the main bony part along with temporal, zygoma, frontal, sphenoid, ethmoid, vomer, nasal and palatal bone. Air cavities, such as maxillary, nasal, ethmoidal, sphenoidal, frontal air sinuses, appear on panoramic images.

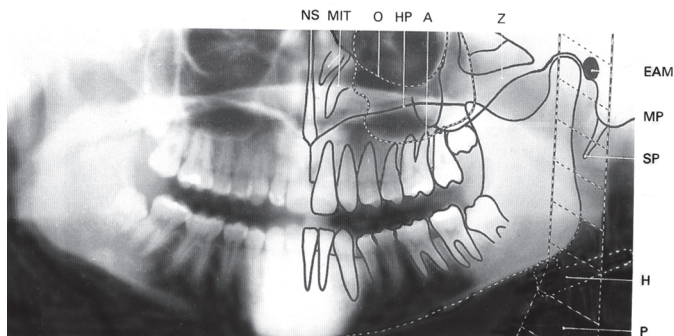


Fig. 15.9: A panoramic radiograph showing shadows. NS - nasal spine, MIT- middle and inferior turbinates, O-orbital margin, HP- hard palate, A-floor of maxillary sinus, Z-zygomatic arch, EAM - external auditory meatus, MP-mastoid process, SP-styloid process, H-hyoid bone, P-plastic head support

The midface region can be visualized for following structures:

- Boundaries and processes of maxilla.
- Maxillary sinuses.
- Pterygomaxillary fissure.
- Zygomatic complex and anterior portion of the zygomatic arch.
- Inferior and lateral orbital rims.
- Nasal cavity and conchae.
- Temporomandibular joint.
- Maxillary teeth with surrounding structures and the alveolus.

The pterygomaxillary fissure appears as an inverted teardrop, which is present at the posterior border of the maxilla. The pterygoid spine of the sphenoid bone is present at the posterior border of the pterygomaxillary fissure.

In Lefort fractures of the maxilla pterygoid plates are involved and also there is evidence of disturbances of the

integrity of the pterygomaxillary fissure in the panoramic image.

The inferior, lateral and upper borders of the maxillary sinuses on both sides are visualized in the panoramic image. The border should be intact if any break appears that indicates fracture especially in the fracture of the floor of orbit which gives hanging drop sign in the maxillary sinus. The maxillary sinus is also examined for polyp, mucous retention cyst or radio-opaque appearance due to mucoperiosteal thickening. The zygomatic complex is a very complex anatomic area with its three processes, frontal, temporal and maxillary. The zygomatic process of the maxilla arises over the maxillary first and second molar. The maxillary sinus can pneumatize the zygomatic process of the maxilla up to the zygomaticomaxillary suture which gives the appearance of an elliptical, radiolucency in the maxillary sinus, superimposed over the roots of a molar tooth, on a panoramic image.

The zygomaticotemporal suture line which is present in the middle of the zygomatic arch should be visualized for any break in the fracture of the zygomatic arch.

The nasal fossa may show the nasal septum, inferior concha including both the bone and its mucosal covering. Any deviation of nasal septum or break and mucosal thickening can be visualized on the panoramic image.

Teeth

Evaluate the teeth and surrounding structures, any gross caries, periapical and periodontal disease may be evident. All the teeth of the mandibular and maxillary dentition are demonstrated on the panoramic image. Identify all impacted, erupted and developing teeth, and the teeth should be examined for gross abnormalities of number, position and anatomy. Any endodontic obturations and fixed restorations

should be noted. The number and configurations of the roots, the mandibular canal and the relationship of root to the floor and posterior wall of the maxillary sinus, the maxillary tuberosity, abnormalities of pericoronal and periradicular bone must be carefully studied.

Improper Positioning of the Lips and Tongue

If the patients, lips are not closed on the bite block during the exposure of a panoramic film, a dark radiolucent shadow obscure the anterior teeth. If the tongue is not in a contact with the palate a dark radiolucent shadow obscure the apices of the maxillary teeth.

This error can be prevented by instructing the patient to close the lips around the bite block and raise the tongue up to the palate during the exposure of the film.

Chapter 16

Cephalometric Radiography

INTRODUCTION

Cephalometric radiography is used in orthodontics and orthognathic surgery to assess the relationship of the teeth to the jaws and jaws to the rest of the facial skeleton. This projection demonstrates the bones of the face and skull as well as the soft tissue profile of the face and this can be utilized in the assessment of the face of the patient pre- and postoperatively. In cephalometry the measurements and comparison of specific points, distances and lines within the facial skeleton are important. The soft tissue profile of the face is obtained by using a film which serves to remove some of the X-rays that pass through the soft tissue of the face (Fig. 16.1).

Indications

The main indications of cephalometric radiography are in orthodontics and orthognathic surgery.

In orthodontics, the indications are:

- To diagnose and confirm the underlying skeletal and/or soft tissue abnormalities.
- Treatment planning.
- Progress of treatment monitored.
- Appraisal of treatment results.

In orthognathic surgery, the indications are:

- In diagnosis of the abnormalities.
- In preoperative evaluation of skeletal and soft tissue patterns.
- To assist in treatment planning.
- Postoperative appraisal of the result of surgery.



Fig. 16.1: Cephalogram showing soft tissue structures

Equipment

The following equipments are needed:

1. Cephalostat or craniostat (Fig. 16.2):
 - a. *Head stabilizing and positioning apparatus:* The stabilizing apparatus with ear rods with correct head position is required.
 - b. *Fixed anti-scatter grid:* This is used to stop photons scattered within the patient reaching the film.
 - c. *Cassette holder.*
 - d. *Aluminum wedge filter:* This is a part of the cephalostat and positioned between the patient and the anterior



Fig. 16.2: The Rotograph plus version can be equipped with a cephalometric arm that can be retrofitted in field at any time to expand applications to the orthodontic field. Rotograph plus is also available as “ST” version that provides the best possible price/performance ratio when only the panoramic exam is required

part of the cassette. It is attached to the tubehead covering the anterior part of the emerging beam. This filter selectively allows the X-ray beam in the region of soft tissues. This enables to visualize the soft tissue profile in the radiograph.

2. Cassette.
3. X-ray generating apparatus.

Cassette is usually 18×25 cm containing intensifying screens and indirect-action film.

X-ray Generating Apparatus

This apparatus is in fixed position relative to the cephalostat (approximately 2 meter). The X-ray beam is produced by the apparatus.

- The X-ray beam should have sufficient penetrating power to reach the film.
- Parallel in nature, so that the midpoint S, N and A are as sharp as possible.
- Collimated to restrict the area of the patient irradiated to the required cranial base and facial skeleton.

PROJECTIONS

These are of two types:

- True cephalometric.
- Posteroanterior cephalometric view of the jaws.

True Cephalometric

Cephalometric means true lateral skull radiograph taken in the cephalostat. The view in orthodontic lateral skull radiograph the patient should be facing to right (Fig. 16.3).

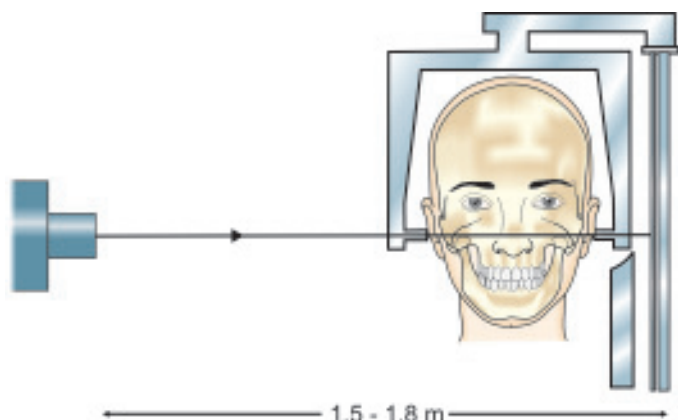


Fig. 16.3: The diagram is showing the relationship between the X-ray forehead and the film. The head is fixed parallel to the film

In true cephalometric (lateral skull radiograph):

- The film should be parallel to the sagittal plane of the patient's head.
- The X-ray beam should be perpendicular to the film and sagittal plane.

Cephalometric Posteroanterior of Jaws (PA View)

This projection is similar to the PA view of the jaws. This is suitable for assessment of facial asymmetries and for the operative and postoperative comparisons in orthognathic surgery involving the mandible.

In this technique the head-stabilizing apparatus of the cephalostat rotated through 90° . The forehead nose position should be horizontal and perpendicular to the film. The X-ray beam is focused horizontal through the cervical spine at the level of rami of the mandible (Fig. 16.4).

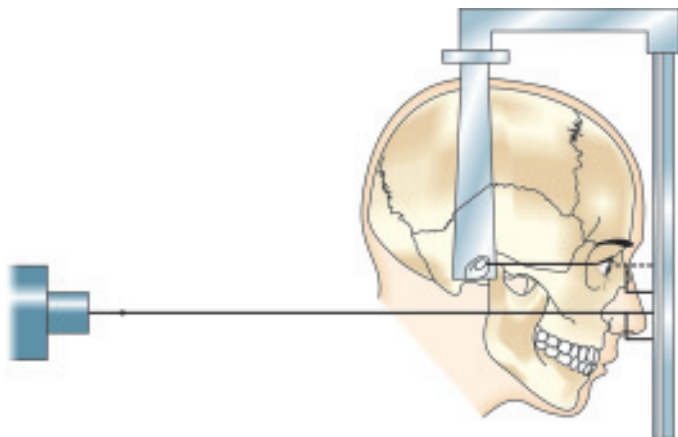


Fig. 16.4: Position of the patient and X-ray beam which is horizontal through the rami in PA view

CEPHALOMETRIC ANALYSIS

The main cephalometric points and measurements include (Figs 16.5 and 16.6):

1. **Sella (S):** The center point of the sella turcica or pituitary fossa.
2. **Orbitate (Or):** The lower most point on the infraorbital margin.
3. **Nasion (N):** The anterior most point on the frontonasal suture.
4. **Anterior nasal spine (ANS):** The tip of the anterior nasal spine.
5. **Posterior nasal spine (PNS):** The tip of the posterior spine of the palatal bone in the hard palate.
6. **Supraspinale (point A):** The deepest point in the bony outline between the ANS and prosthion.
7. **Subspinale (Point):** The deepest point in the bony outline between the infradentate and the pogonion.
8. **Pogonion (Pog):** The most anterior point of the bony chin.
9. **Gnathion (Gn):** The most anterior and inferior point on the bony outline of the chin.
10. **Menton (Me):** The lower most point on the bony outline of the mandibular symphysis.
11. **Gonion (Go):** The most lateral external point at the junction of the horizontal and ascending rami of the mandible.
12. **Articulase (Ar):** The point of intersection of the dorsal contours of the posterior border of the mandible and temporal bone.
13. **Porion (Po):** The uppermost point of the bony external auditory meatus.
14. **Infradentale (Id):** The most anterior point the alveolar crest situated between the lower central incisors.
15. **Prosthion (Pr):** The most anterior point of the alveolar crest in the premaxilla situated between the upper central incisors.



Fig. 16.5: The main points in cephalometric tracing

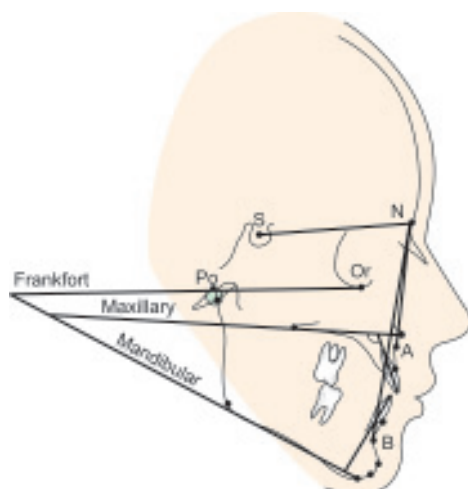


Fig. 16.6: The planes and angles in cephalometric tracing

16. **Basion (Ba):** The median point of the anterior margin of the foramen magnum.
17. **Bolton point (Bo):** The highest point at the posterior condylar notch of the occipital bone.

LINES AND PLANES IN CEPHALOMETRICS

These lines are obtained by connecting two landmarks. These lines or planes can be classified into horizontal and vertical planes based on their orientation.

Vertical Line

1. **A-Pog line:** A line from point A on maxilla to pogonion on the mandible.
2. **Facial plane:** A line from the anterior point of the frontonasal suture to the most anterior point of the mandible.

Horizontal Planes

1. **Mandibular plane:** Several mandibular planes are used in cephalometrics:
 - a. A line connecting the gonion and menton (Down analysis).
 - b. A line tangent to the lower border of the mandible (Tweed analysis).
2. **SN plane:** The line between the center of selle turcica (S) and the anterior point of the frontonasal suture (N). It represents the anterior cranial base.
3. **Frankfort horizontal plane:** The line or plane that connects the lower point of the orbit (Or) and the superior point of the external auditory meatus (Po).
4. **Basion-nasion plane:** The line connection between basion (Ba) and nasion (N). It represents the cranial base.

5. **Bolton's plane:** The plane that connects the Bolton's point (Bo) to the occipital, condyles and nasion (N).
6. **Occlusion plane:** It is a denture plane bisecting the posterior occlusion of the permanent molars and premolars and extends anteriorly.
7. **Palatal plane:** The line joining the anterior nasal spine of the maxilla and posterior nasal spine of the palatine bone.
8. **Maxillary plane:** A transverse plane joining the anterior and posterior nasal spines.
9. **SNA:** Anteroposterior position of the maxilla, represented by point A to the cranial base.
10. **SNB:** Anteroposterior position of the mandible represented by point B to the cranial base.
11. **ANB:** Anteroposterior relation of the maxilla to the mandible.

Chapter 17

Radiography of the Temporo- mandibular Joint

In dental practice the problems of *temporomandibular joint* (TMJ) are common. In dental clinics TMJ imaging can be done and some may have to refer to advance centers for specialized radiographs of TMJ.

ANATOMY OF TMJ

The TMJ imaging study is clear by understanding the hard and soft tissue anatomy of the TMJ. The temporomandibular joint is bounded laterally by the zygomatic arch and medially by the petrous ridge of the temporal bone. In radiographs we should be able to identify the external auditory meatus of the ear, the mandibular condyle, the articular fossa, the neck of the condyle and the articular eminence (Fig. 17.1). The soft tissue structures, such as articular disk, external pterygoid muscles, are not seen in the conventional radiographs. The articular disk which is a fibrocartilaginous structure appears radiolucent is seen in specialized imaging technique such as MRI.

Pathological lesions of TMJ which can be seen in radiographs are:

- Fractures
- Benign and malignant tumors
- Arthritic changes
- Ankylosis

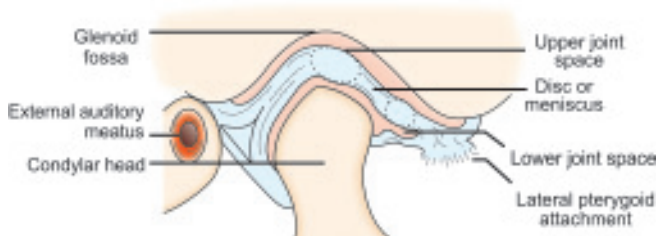


Fig. 17.1: Diagram of TMJ in sagittal section

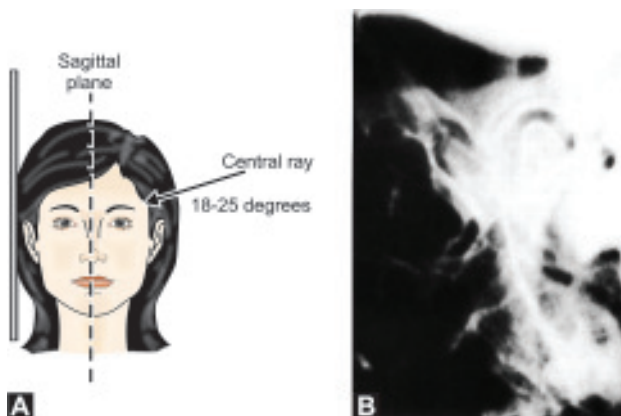
- Disk displacement and perforation
- Fibrous adhesion
- Congenital absence of structures
- Hypertrophy of condyle and osteolytic changes in condyle.

These radiographs can be taken in open, closed and rest position of condyle.

Transcranial Temporomandibular Joint Projection

Costen, Lindloof and Greweock defined Transcranial techniques. The limitation of the technique is that only the lateral one-third of the joint space can be visualized (Figs 17.2A and B).

Transcranial projection is the most common TMJ radiograph used to visualize the joint. 5×7 inch film is used and radiographs are taken of both right and left side in both the open and the closed position. Four views can be taken on an 8×10 inch film by placing appropriate lead shield.



Figs 17.2A and B: A transcranial projections: (A) Diagram showing direction of central ray 18 to 25 degrees to the horizontal. (B) Radiograph of the TMJ

The patient's head is positioned parallel to the cassette with the side to be imaged closest to the cassette. The central ray of the X-ray beam is directed from the opposite side of the head from the condyle being radiographed, approximately 2 ½ inches above and ½ inch in front of the external auditory meatus. The X-ray beam is positioned at a vertical angulations of 20 to 25 degrees. The open surface of the position indicating device approximates the skin. An intensifying screen of 7 to 15 impulses with a fast film and an average exposure time at 65 kVp and 10 mA is used.

Transpharyngeal Projection

The transpharyngeal projection gives a sagittal view of the medial pole of the condyle. The X-ray beam is directed superiorly at - 5 degrees through the sigmoid notch of the opposite across the pharynx at the condyle under investigation side and 7 to 8 degrees from the anterior. The patient holds the film cassette against the side of the face over the TMJ of interest. The film and the midsagittal plane of the head are parallel. The patient's mouth is open and a bite block is inserted for stability. This view is taken to visualize both condyles to allow comparison.

The transpharyngeal projection is effective for visualizing erosive changes of the condyle. But this view provides limited diagnostic information because the temporal component is not imaged well.

Transorbital Projection

This projection provides an anterior view of the TMJ, perpendicular to transcranial and transpharyngeal projections. The X-ray beam is directed from the front of the patient through the ipsilateral orbit and TMJ of interest. The cassette is placed behind the patient's head, perpendicular to

the X-ray beam. The patient opens the mouth maximally to position the condyle at the sum with of the articular eminence and avoiding superimposition of the articular eminence on the condyle. This view is useful for visualizing condylar neck fractures.

Panoramic Projection

This is the most common projection to visualize both right and left joints in the lateral plane as well as an over all view of mandible and maxilla can be seen. These views are used for screening to detect any TMJ pathologic conditions, if this view indicates any pathologic process a more advance projection, such as CT Scan or MRI, can be used for diagnosis. The glenoid fossa, candyle, articular eminence can be seen but not the articular disk (Fig. 17.3).

After the discovery of X-ray in 1895, imaging studies have progressed from transcranial views to more specialized computed tomography (CT) and magnetic resonance imaging (MRI) examinations. Transcranial views of the TMJ were defined between 1930s and 1950s. CT examinations began in the late 1970s and 1980s and MRI in the late 1980s and 1990s.

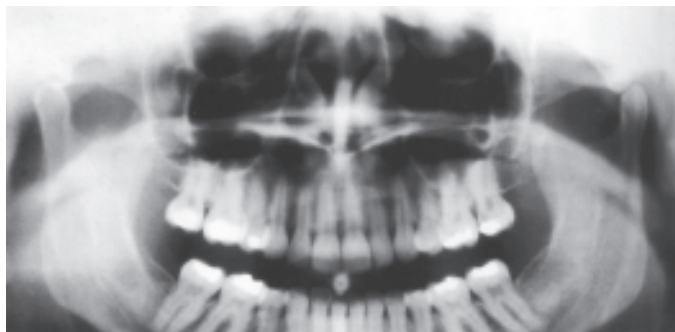


Fig. 17.3: Panoramic radiograph showing both condyles

Submentovertex (Basaler Projection)

This view is useful for viewing condyles, zygomatic arches, lateral wall of the orbit sphenoidal and maxillary sinuses and pterygoid plates.

The structures in the base of the skull can be visualized clearly in this view.

The submentovertex or base view is taken with the head positioned so that the canthomeatal line is paralld to the film and perpendicular to the central X-ray beam. The central X-ray beam enters the skull in the midline between the mandibular angles.

Conventional Tomography

Tomography gives a two dimensional picture of a three dimensional structure object in front of and behind the selected plane of imaging which are blurred or obscured. This obviates superimposition of overlapping structures. The images in tomography are better than panoramic and in some ways equivalent to a CT scan. The articular fossa, neck and head of the condyle are visible but not the articular disk.

In tomography the X-ray tube moves in one direction while the X-ray film move in the opposite direction. The result is a variable fulcrum point. Selected body sections can be obtained by mechanically moving the fulcrum point up or down. Optimal TMJ imaging studies are obtained with a wide area of tube travel 30 to 40 degrees and thin section collimation 1 to 2 mm thick slices. X-ray tube motion can be linear or complex (circular).

Computed Tomography

Computed tomography (CT) facilitates viewing of an area in three planes and is an excellent means for examining the bones

of the TMJ. However, this does not include diagnostic images of the articular disk.

The original CT scan times were approximately 1 to 2 minutes per slice and 1 to 5 minutes of computer reconstruction time per slice. Dynamic spiral CT is extremely fast with slice acquisition times are under 1 second. Other application of spiral CT technology are three dimensional imaging, CT angiography and virtual reality imaging. CT is extremely useful for revealing skeletal abnormalities of the TMJ but is of limited value in soft tissue evaluation such as the disk cartilage is about 3 mm thick and its soft tissue CT characteristics are not unique. MRI have excellent soft tissue resolution and is useful for localization of the disk cartilage. Thus the main use of CT technique is in detection of skeletal abnormalities (Fig. 17.4).

MRI

Magnetic resonance imaging (MRI) is a very effective for viewing soft tissue especially the articular disk of the TMJ. The image which is radiolucent on a CT scan will appear

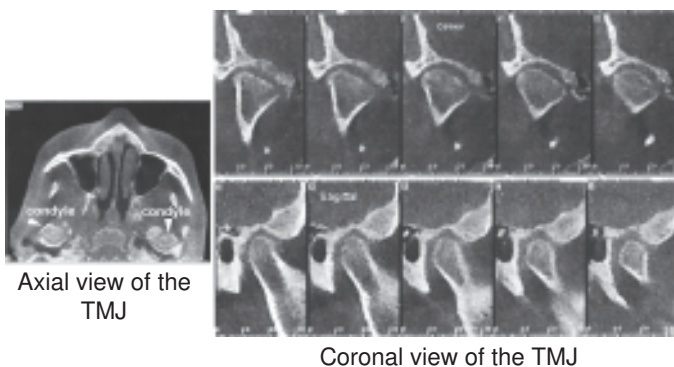


Fig. 17.4: CT technique

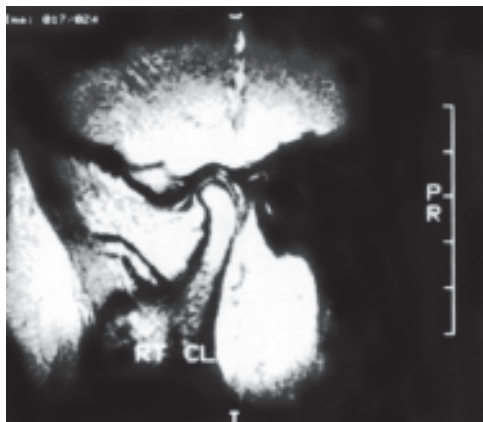


Fig. 17.5: MRI of the TMJ showing articular disk

radiopaque on an MRI, which indicates high soft tissue density or a strong signal. The image which is radiolucent on a CT scan will appear radiolucent on an MRI indicating low soft tissue density or a weak signal.

MRI studies should be obtained in multiple planes of imaging sagittal and coronal using variable pulse sequences to create selected T1- and T2-weighted images (Fig. 17.5).

Contrast Investigation

Contrast media (usually with iodine media) containing high atomic number elements absorb radiation well and improve the visualization of cavities. This is used in investigation of the temporomandibular joint which is known as arthrography.

Contraindication of contrast investigation are sensitivity to the medium (iodine sensitivity) and introduction into an acutely infected area because in this condition it causes more inflammation.

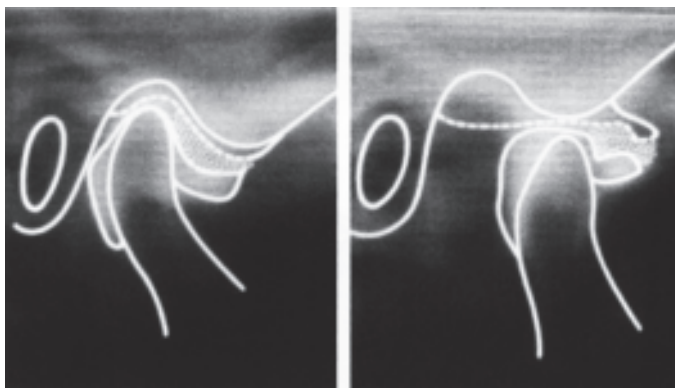


Fig. 17.6: Images of arthrography of TMJ

TMJ Arthrography

Contrast medium is usually introduced into the lower joint space. Under fluoroscopic guidance image intensifier the findings are recorded on videotape (Fig. 17.6). The patient is positioned in supine position with the head turned 8° away from the side being examined. The tube above is tilted $5-10^\circ$ caudally as for a lateral oblique transcranial TMJ projection. The local anesthetic solution is injected into the retrocondylar tissues and beneath the articular tubercle. The patient's mouth is closed and an 18 G (1.2 mm $\times$ 45 mm) cannula is directed against the posterior surface of the condyle. The patient's mouth is opened and condylar movement is felt with the cannula.

The position of cannula is checked fluoroscopically and the needle withdrawn. The cannula is then advanced medially into the posterior part of the joint. The contrast media (water soluble nonionic iohexol 500 or iopamidol 300) of about 0.25 ml containing 300 mg I/ml is injected and joint cavity is visualized. Another cannula is inserted 10 mm anterior to the

lower and directed against the posterior slope of the articular tubercle. On bone contact the needle withdraw and the cannula is advanced medially into the upper compartment and 0.3 ml of contrast medium injected.

Indications of Arthrography

1. Investigation of internal derangement.
2. Any perforation or adhesion of the articular disk.
3. Disk displacement.

Chapter 18

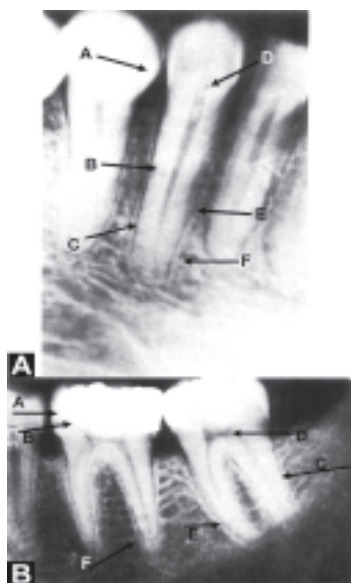
Normal Anatomical Structures in Radiographs: Intraoral Radiographs

The knowledge of normal anatomical landmarks is important from the point of view of any structural variation from normal structures. One must be familiar with the correct identification and interpretation of radiograph.

The component structures of the tooth and its supporting tissues are well-defined and can be demonstrated best in younger persons.

RADIOGRAPHIC APPEARANCE OF ANATOMY OF TOOTH AND ITS SUPPORTING STRUCTURES

1. The enamel, which is the densest of the hard structures of the tooth, is seen as a very radiopaque band that covers the coronal portion and tapers to a fine edge at the cervical margin of the tooth (Figs 18.1A and B).
2. The dentin, which exhibits a lesser degree of radiopacity than does enamel, accounts for the largest portion of the hard structures of the tooth.
3. The cementum, which covers the surface of the root of the tooth, has a lesser degree of radiopacity than dentin.
4. The pulp chamber and the root canal are visualized as a continuous radiolucent space in the center of the tooth, which extends from the coronal portion to the apex of the root.
5. The lamina dura, which represents the wall of the alveolar tooth socket, is seen as a radiopaque line, which follows a course parallel to the root of the tooth.
6. The periodontal membrane space is depicted by a fine radiolucent line that is situated between the lamina dura and the root of the tooth surrounding. The periodontal space, the cortical bone on the crest of the alveolar ridge, is continuous with the lamina dura.



Figs 18.1A and B: Radiographs of (A) anterior teeth and (B) Posterior teeth showing A—enamel, B—dentine, C—cementum, D—pulp, E—periodontal space, F—alveolar bone

NUTRIENT CANALS

The nutrient canals here referred to those that contain blood vessels and nerves that supply the teeth, interdental spaces and gingivae. In the radiograph they are evidenced by radiolucent lines of fairly uniform width which sometimes exhibit radiopaque borders (Fig. 18.2).

The nutrient canals of the mandible are more often visualized in the radiograph than are those of the maxilla, due to its large size. The mandibular canal is seen in a high percentage of cases. It follows a path that also is in close proximity of the roots of the premolars and the first and second molars.



Fig. 18.2: Arrows show nutrient canals

Nutrient canals that arise from the mandibular canal are those that extend upward into the interdental space, and those that extend directly to the periapical foramina of the root of the tooth. The lateral canals are very small and are rarely visualized in the radiograph. Of the nutrient canals of the maxilla that supply the teeth and their supporting structures, the canal or groove that the posterior superior alveolar artery occupies is the one that is most often visualized.

In the anterior region of the maxilla the nutrient canals that are occupied by terminal branches of the anterior superior alveolar artery are seldom visualized when the teeth are present, although the interdental canals often come into view when the jaw becomes edentulous.

ANATOMICAL STRUCTURES OF MAXILLA

Anterior Palatine (Incisive) Canal

The incisive canal through which the nasopalatine nerves and the anterior branch of the descending palatine vessels pass is

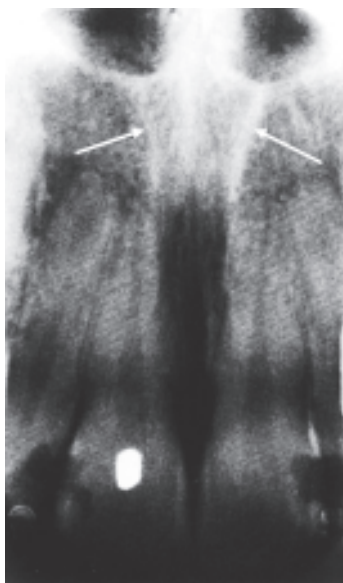
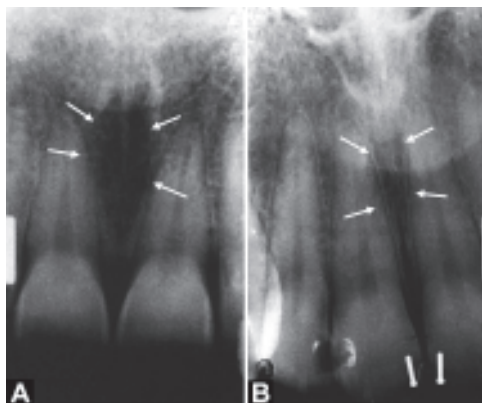


Fig. 18.3: Arrows show the lateral border of incisive canal

not always visualized in the radiograph. It varies greatly in width and length and when seen it is evidenced by two radiopaque lines which extend downward, one from the floor of each nasal fossa, and which depict the lateral walls of the canals. These lines tend to converge and they fade out imperceptibly at the lateral borders of the anterior palatine foramen (Fig. 18.3).

Anterior Palatine (Incisive) Foramen

The anterior palatine foramen through which the nasopalatine nerve and vessels emerge is situated in the anterior portion of the midline of the palate. Its anterior border may closely approach the crest of the alveolar ridge, or it may be situated



Figs 18.4A and B: Both these figures (A and B) show the incredible size of the incisive foramen

at some distance posterior to it. Its image varies in relation to the roots of incisor teeth, and ranges from a position near the crest of the alveolar ridge to one that may be at the level of the apex of the roots. In some instances its image may be superimposed on the apex of the root of the central incisor teeth, and it may then be mistaken for a periapical lesion. It is almost always elliptical in shape and variable in size (Figs 18.4A and B). A cyst of the incisive canal with which it may be confused has a well-defined border and tends to be round.

Superior Foramina of the Incisive Canal

Foramina through which the nasopalatine nerves and branches of the descending palatine vessels pass downward into the incisive canal are most often visualized in radiographs taken for the maxillary lateral incisors and canines, and when the central rays are directed onto the film at a high vertical angle.

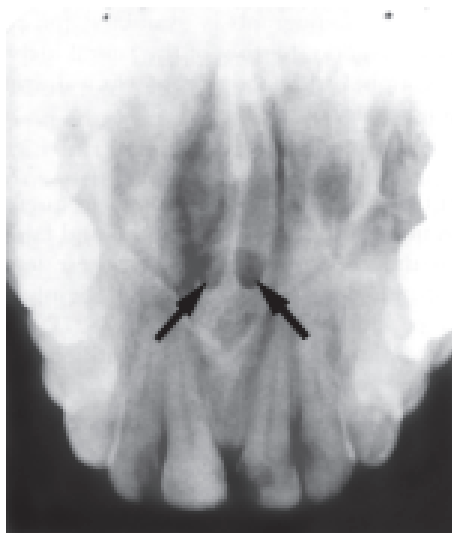


Fig. 18.5: Arrows show the two superior foramina

The superior foramina appear as two small round radiolucencies located superior to the apices of the maxillary central incisors (Fig. 18.5).

Median Palatine Suture

The median palatine suture appears as a thin radiolucent line between the maxillary central incisors. The median palatine suture is bounded by dense cortical bone on both sides as radiopaque. The median palatine suture becomes less distinct with age due to fusion with age (Fig. 18.6).

Lateral Fossa (Canine Fossa)

The lateral fossa appears as a radiolucent area between the maxillary canine and the lateral incisors. This smooth

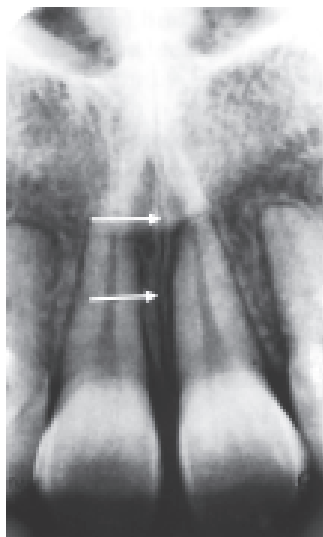


Fig. 18.6: Arrows show median palatine suture

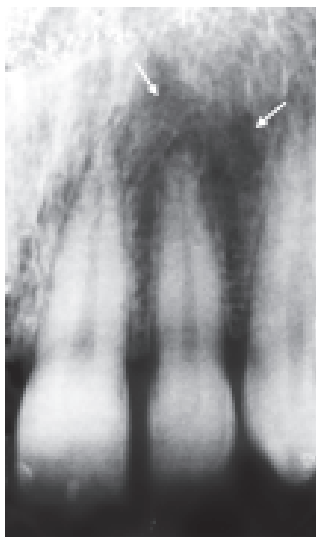


Fig. 18.7: Arrows show radiolucent area of lateral fossa

depressed area of the maxilla located between the canine and the lateral incisors (Fig. 18.7).

Nasal Cavity

It appears as a large pear shaped radiolucancy above the maxillary central incisors. The nasal cavity is separated by a bony portion, the nasal septum, into right and left nasal cavities (Fig. 18.8).

Nasal Septum

The nasal septum appears as a vertical bony radiopaque portion dividing the nasal cavity (Fig. 18.9).



Fig. 18.8: Arrows show two nasal cavities on both sides of nasal septum

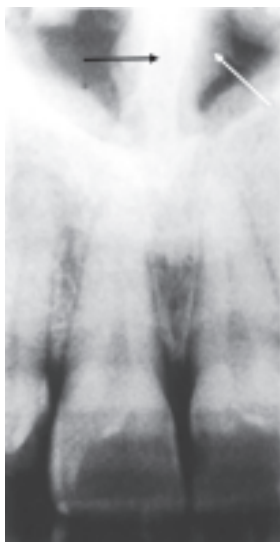


Fig. 18.9: Arrows show radiopaque shadow of nasal septum

Floor of the Nasal Cavity

It appears as a dense radiopaque band of bone above the maxillary incisors (Fig. 18.10).

Anterior Nasal Spine

Anterior nasal septum appears as a V-shaped radiopaque area located where the floor of the nasal cavity and nasal septum meet (Fig. 18.11).

Maxillary Sinus

The maxillary sinus are paired bony compartment located above maxillary premolar and molar teeth. In radiograph the



Fig. 18.10: Arrows show the floor of the nasal cavity

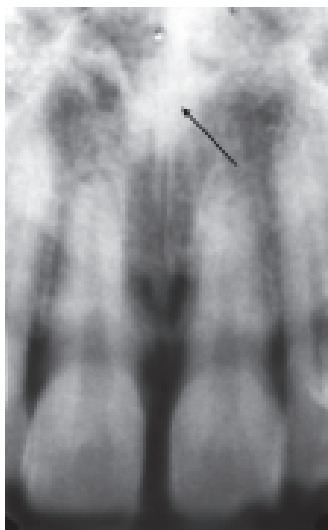


Fig. 18.11: Arrows show V-shaped anterior nasal septum

maxillary sinus appears as a radiolucent area located above the apices of premolar and molar teeth. Sometimes the floor of the maxillary sinus may dip between the apices of the maxillary first molar tooth but this does not indicate perforation of the sinus by the root apices. The floor of the maxillary sinus appears as a radiopaque line which is due to the presence of dense cortical bone (Fig. 18.12).

Inverted Y

The inverted Y appears in the periapical radiograph as a radiopaque upside down Y formed by the intersection of the lateral wall of the nasal cavity and the anterior border of the maxillary sinus. The inverted Y-line is located above the maxillary canine (Fig. 18.13).

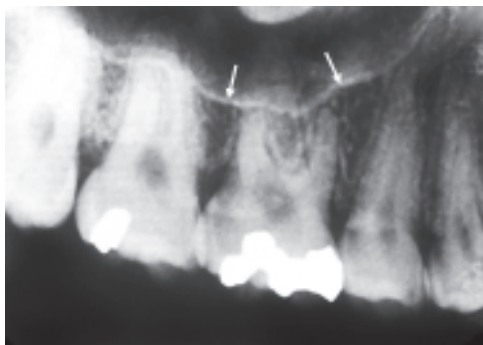


Fig. 18.12: Arrows show the floor of the maxillary sinus



Fig. 18.13: Arrows show radiopaque inverted Y shaped

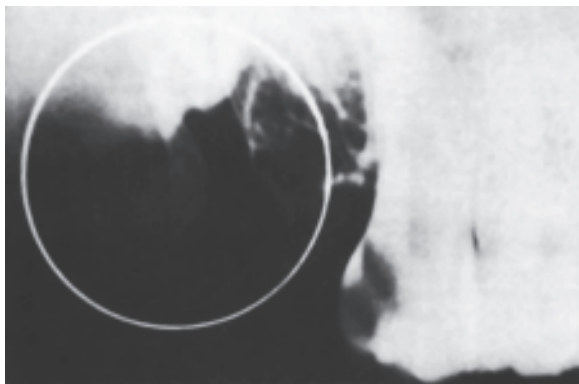


Fig. 18.14: Radiograph showing radiopaque bulge of maxillary tuberosity

Maxillary Tuberosity

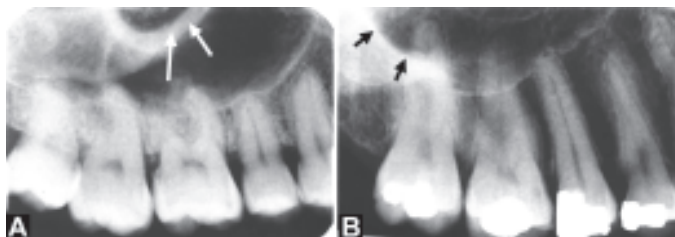
The maxillary tuberosity appears as a radiopaque bulge distal to the third molar region (Fig. 18.14).

Zygomatic Process of Maxilla

The zygomatic process of the maxilla arises on the lateral surface directly above the first molar region. It may have a board narrow base, and it extends away from the surface in an upward direction of varied degree. In dental radiographs it is usually seen as an inverted J- or V-shaped radiopaque loop, located superior to the maxillary first molar region represents the cortex of the inferior aspect of the process (Figs 18.15A and B).

Malar Bone

The malar bone, which is a continuation of the zygomatic process and extends posteriorly, is seen as a diffuse



Figs 18.15A and B: Arrows show radiopaque loop of zygomatic process of maxilla

radiopaque band extending posteriorly from the zygomatic process of the maxilla. Superimposition of these structures often can be avoided by altering the vertical angulation of the central rays in making the exposure.

Hamular Process

The hamular process is a bony projection that arises from the sphenoid bone and extends downward and slightly posteriorly. In the radiograph it appears as a hook-like radiopaque projection and its image is seen in close proximity to the posterior surface of the tuberosity of the maxilla. It varies greatly in length, width and shape from patient to patient (Fig. 18.16).

Nasolacrimal Duct

The orbital entrance of the nasolacrimal duct is almost always visualized in occlusal views of the palate. It is seen as a fairly large, rounded, radiolucent area superimposed on the posterior region of the hard palate, and at the junction of the images of the medial wall of the maxillary sinus and the lateral wall of the nasal fossa (Fig. 18.17).



Fig. 18.16: Arrows show a hook-like radiopaque projection of hamular process

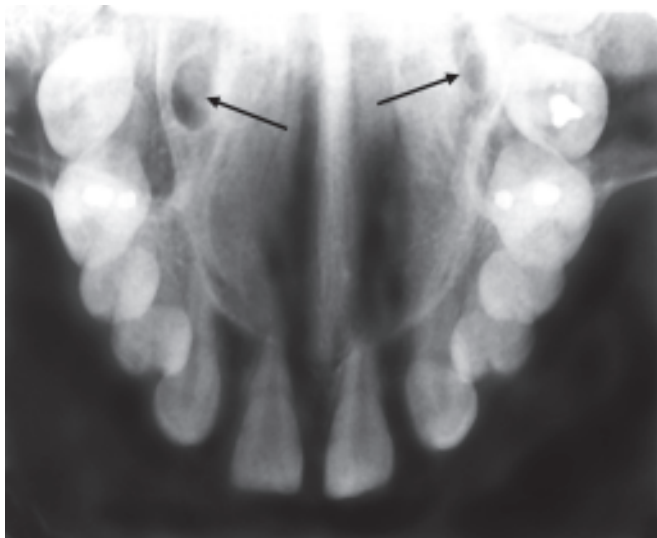


Fig. 18.17: Arrows show two nasolacrimal duct on both sides

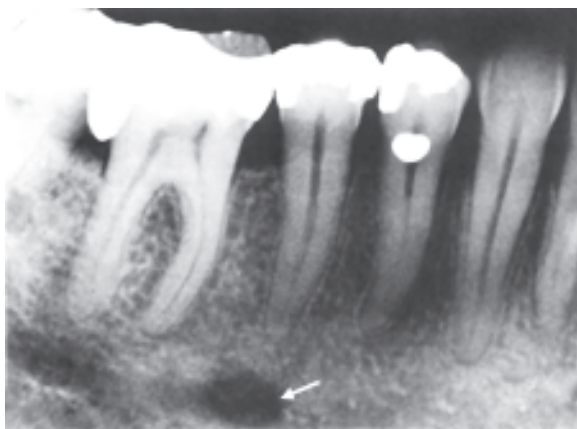


Fig. 18.18: Arrows show radiolucent shadow of mental foramina

ANATOMICAL STRUCTURES OF MANDIBLE

Mental Foramen

The mental foramen through which the mental nerve and blood vessels emerge is seen as an oval or round radiolucent area in the mandibular premolar region. Its location varies in relation to the roots of the premolar teeth and its image may be seen inferior to at the same level as, or superior to the apex of a root. It may be situated directly opposite either of the premolars, or between them (Fig. 18.18). Its image may be superimposed on the apex of the root of a tooth, in which event it may be mistaken for a periapical lesion. An intact lamina dura, when visualized, should serve to differentiate them. It is in evidence more often in the edentulous mandible. If the alveolar bone has undergone marked resorption and atrophy, it may be situated near the superior border of the ridge.

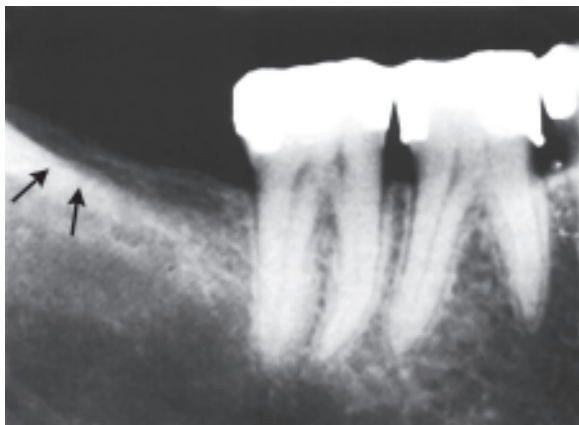


Fig. 18.19: Arrows show radiopaque line of external oblique ridge

Lingual Foramen

The lingual foramen through which a branch of the incisive artery emerges is situated on the lingual surface of the mandible at the symphysis. It is evidenced by a small radiolucent dot, which is brought into prominence by a radiopaque circle that surrounds it and represents the genial tubercles.

External Oblique Ridge

The external oblique ridge is a continuation of the anterior border of the ramus that passes forward and downward over the outer surface of the body of the mandible to the mental ridge. It is visualized as a radiopaque line of varied width and density, which passes anteriorly and across the molar region (Fig. 18.19). In the edentulous mandible where the alveolar process has undergone complete resorption, it may assume a position that is at the level of the superior border of the mandible.

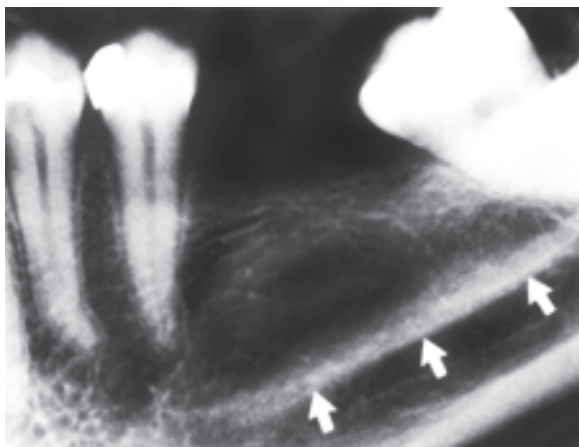


Fig. 18.20: Arrows show radiopaque shadow of mylohyoid ridge

Mylohyoid (Internal Oblique) Ridge

The mylohyoid ridge begins on the medial and anterior aspect of the ramus and extends downward and forward diagonally on the lingual surface of the mandible toward the lower border of the symphysis. It varies greatly in size and since its posterior portion is the most prominent, it is most often visualized where it crosses the retromolar and molar regions. It may be evidenced by a radiopaque line, which varies from one that is very faint and narrow to one that is very broad and dense. Its course forward usually is on a lower level than that of the external oblique ridge, and its image is sometimes superimposed on the roots of the molar teeth (Fig. 18.20). The bone seen inferior to the ridge appears to be abnormally radiolucent and may be mistakenly thought to represent a cystic condition.

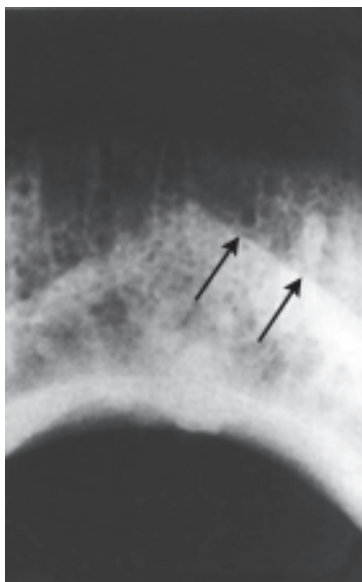


Fig. 18.21: Arrows show radiopaque line of mental ridge

Mental Ridge

The mental ridge is situated on the anterior aspect and near the inferior border of the mandible. It varies in prominence and extends from the premolar region to the symphysis. It is visualized as a radiopaque line that appears below the apices of the roots of the anterior teeth and that usually takes an upward turn as it approaches the symphysis. In some instances the image of the ridge may be superimposed on the roots of the teeth (Fig. 18.21).

Coronoid Process

The image of the coronoid process of the mandible often appears in periapical radiographs in the molar region of

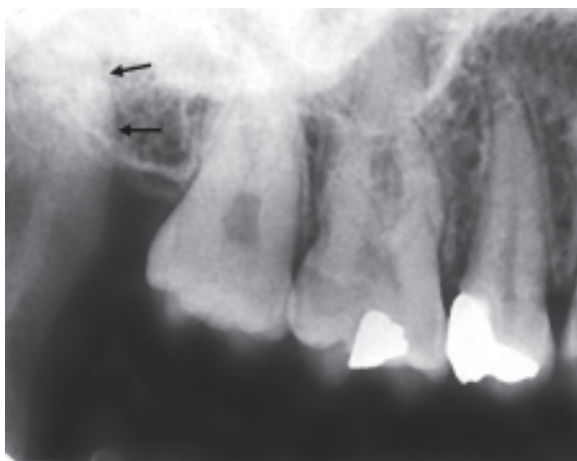


Fig. 18.22: Arrows show radiopaque shadow of coronoid process

the maxilla. As the mouth is opened, the process moves forward and, therefore, it comes into view most often when the mouth is opened to its fullest extent at the time the exposure is made. It is evidenced by a tapered or triangular radiopacity, which may be seen below or, in some instances, superimposed on the molar teeth and maxilla (Fig. 18.22).

Genial Tubercles

Genial tubercles are tiny protuberance of bone where the geniohyoid and genioglossus muscles attach. It is located on the lingual side of the mandible. In radiograph genial tubercles appear as a ring-shaped radiopacity below the apices of the mandibular incisors. Although usually relatively small, they may be fairly large and extend outward from the surface as spinous processes (Fig. 18.23).

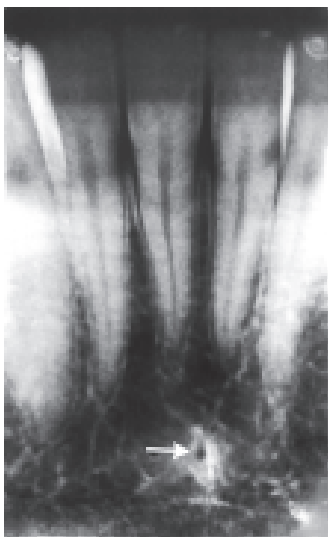


Fig. 18.23: A ring-shaped radiopacity at the apices of mandibular incisors

Mandibular Canal

The mandibular canal extends from the mandibular foramen to the mental foramen and contains the inferior alveolar nerve and blood vessels.

In radiograph mandibular canal appears as a radiolucent band surrounded by two thin radiopaque lines that represent the cortical walls of the canal (Fig. 18.24).

Submandibular Fossa

The submandibular fossa is a depressed area of bone located on the inner surface of the mandible below the mylohyoid ridge. It contains the submandibular salivary gland. In radiograph it appears as a radiolucent area in the molar region below the mylohyoid ridge (Fig. 18.25).

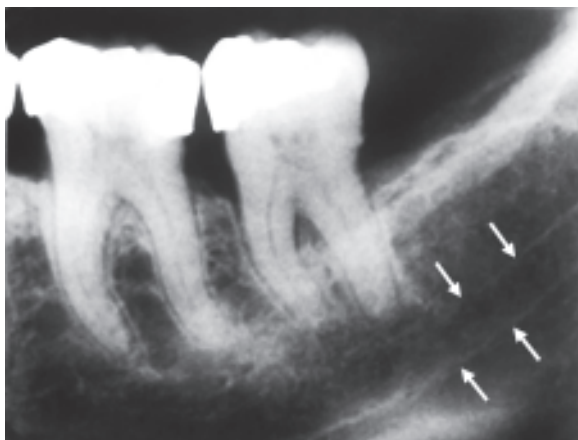


Fig. 18.24: Arrows show radiolucent band surrounded by radiopaque lines

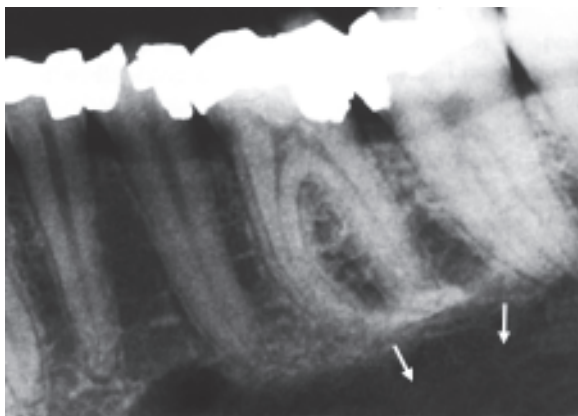


Fig. 18.25: Submandibular fossa appears as a radiolucent area below molars

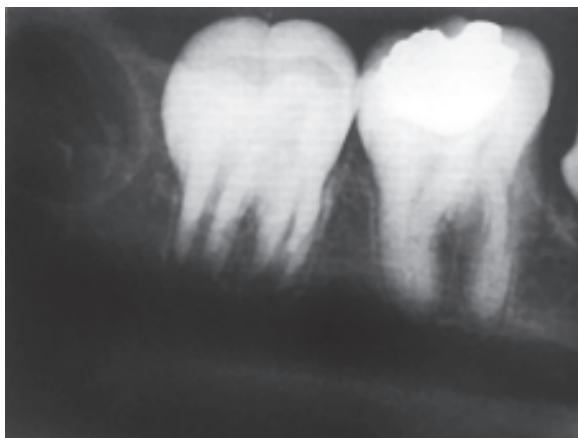


Fig. 18.26: A well-defined round or oval radiolucency of tooth germ

TOOTH GERM AND PAPILLA

The tooth germ when seen prior to the onset of calcification of the tooth is evidenced by a well-defined round or oval area of uniform radiolucency (Fig. 18.26). The formation of the germ of second premolars and third molars is often retarded in relation to the chronologic age of the patient, and cases have been noted in which radiographic evidence of the tooth bud of third molars had not appeared until after the patient had reached 20 years of age. In this event it might be interpreted as being a cyst.

A dentin papilla that is superimposed on the image of the mandibular canal may produce an area of marked radiolucency. This most often occurs with the development of the second and third molars, and should not be mistaken for a periapical lesion.

THE STYLOHYOID CHAIN

The stylohyoid chain consists of the styloid process of the temporal bone, the lesser cornu or horn of the hyoid bone

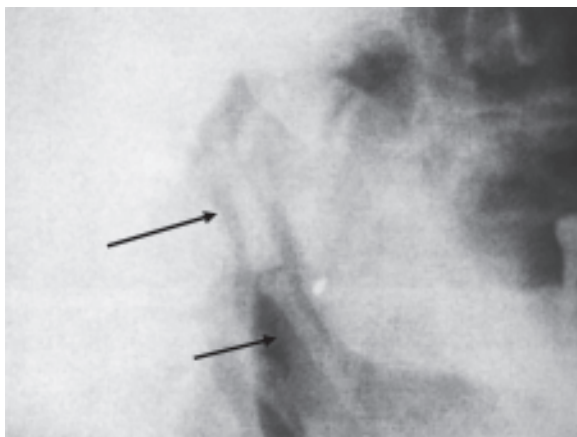


Fig. 18.27: Arrows show the calcified stylohyoid ligament

and the connection, usually the stylohyoid ligament, between these two. It develops from the cartilage of the second branchial or hyoid arch, also known as Reichert's cartilage.

The normal styloid process is cylindric spur of bone that usually tapers gradually toward a pointed free extremity. It varies much in length, usually being from 5 to 50 mm long and it often varies also in thickness, form and shape (Fig. 18.27).

The stylohyoid ligament, the normal representative of the epiphyseal link of the chain, is a band of connective tissue, which is attached to the free extremity of the styloid process and extends to the lesser horn (cornu) of the hyoid bone.

The lesser horns usually ossify a few years after birth and are typically small nodules of bone united to the body of the hyoid bone by fibrous tissue and to the greater horns of the hyoid bone by fibrous tissue or tiny synovial joints.

Chapter 19

Maxillofacial Imaging

In dental radiography, one of the newest technology introduced, is digital imaging. This system uses electronic sensors instead of film for recording the penetration of X-ray photons and sends this information to a computer that digitizes (converts to numbers) these electronic impulses. There the diagnostic image is produced on the monitor of the computer almost instantaneously without any darkroom procedure. Digital imaging was introduced into dentistry in 1987 by Dr Francois Mughen with his RVG System (Radio Visio Graphy).

A. *Importance of diagnostic imaging*

- To obtain a correct diagnosis by providing additional information.
- An appropriate management can be planned.

B. *Selection*

- (a) by obtaining a history
- (b) by a clinical examination

This determines,

- Type of additional information required, if any.
- The best technique for obtaining this information.

C. *Reasons for obtaining imaging information*

- The determination of the nature of a condition.
- The confirmation of a clinical diagnosis.
- The evaluation of the extent of the lesion.
- Monitoring of the progression or regression of a lesion over time.

It is upon the clinician to use diagnostic imaging wisely. Clinician must decide:

- What information is needed?
- Whether imaging is the best way to obtain this information.
- Select the most appropriate technique.
- The radiation dose and cost.
- The availability of the technique.
- An expert is needed to interpret the study.

IMAGING METHODS

Intraoral, occlusal, bitewing and panoramic radiography: Intraoral and panoramic radiography will give majority of images needed for evaluating oral-facial complaints.

INTRAORAL RADIOGRAPHY

Advantage

It provides fine details in visualization of the teeth and supporting bone.

OCCLUSAL X-RAY

Advantages

1. For detecting sialoliths in the submandibular duct.
2. Localizing lesions or foreign bodies (since this is at right angle to the periapical X-ray).
3. Evaluate the buccal and lingual cortex of the mandible for perforation, erosion or expansion.

PANORAMIC RADIOGRAPHY

Advantages

1. It demonstrates a wide view of the maxilla and mandible as well as surrounding structures, neck, head, spine, etc.
2. TMJ, zygomatic arches, maxillary sinuses, nasal cavity and orbits can be visualized in this X-ray (but the sharpness is less and there is overlapping of the shadow).
3. Comparison of right and left side (for any asymmetry) is easier.
4. Bony structures of TMJ (Condyle and Coronoid processes), floor of sinus and floor of the orbit and its integrity.

Other X-ray views are:

- Lateral
- Lateral oblique
- Posteroanterior and anteroposterior
- Submentovertex
- Cephalometric

DIGITAL IMAGING

A digital image is an image formed by the use of an electronic sensor that is connected to a computer (Fig. 19.1). The basic requirements for a digital image are:

1. an X-ray machine
2. an electronic sensor or detector
3. an analog-to-digital converter
4. a computer (or laptop)
5. a monitor



Fig. 19.1: The basic requirements for a digital image

Digital Radiography System (RVG)

RVG (Radiovisiographic System) Digital radiography is a film less dental radiographic system that takes high-resolution diagnostic quality image that requires less than 10% of the X-ray required for traditional images.

The system replaces the tradition film pack with a sensor and it lower down radiation exposure to the patient. The sensor looks like the X-ray film and detects radiation and transmits the information to the computer, which display the image in the monitor.

Digital means the turning data into number or digits. The data is not limited to the numbers it can also be any thing including pictures. Digitized means it can be manipulated analyzed, stored and transmitted electronically.

Techniques

There are three basic types of digital imaging systems:

1. **Direct digital radiography:** This system uses a sensor wired directly to the computer with the sensor either a charged coupling device (CCD) or a complementary metal oxide semiconductor (CMOS).
2. **Indirect digital radiography (storage phosphor):** This wireless system employs a photo stimulable phosphor plate (PSP) and laser beam scanning to produce the image.
3. **Optically scanned digital radiography:** In this system a finished processed radiograph is scanned and digitized scanned.

In the First Technique (CCD or CMOS)

Sensor is a device that transforms the energy from ionizing radiation into an electrical signal that is displayed as an image on a computer monitor within a few seconds. The sensor is housed in a rigid plastic case that is attached to the computer by a long cord.

The sensor is placed in the mouth. The computer is activated and the exposure is made.

Sensor

Sensor is the most important part of the digital radiography, which is placed in the patient's mouth instead of a film. Sensors are available in different sizes no. 0, no. 1 and no. 2 and panoramic films. The sensor and film both have the same field size. Direct sensors have wires leading to the image processor and solid-state electronic devices. The most commonly used sensor is CCD, which is a chip of pure silicon that is divided into two dimensional display called pixels. When X-ray or light photons interact with a CCD, an electric charge is created and stored. After the exposure is completed the charges on the CCD are sequentially removed electrically creating continuous analog output signal. An analog signal represents data in a continuous mode. This information is converted to digital units that can be assigned numbers. An analog to digital converter is used to convert the analog output signal to a digital signal that is then sent to the computer.

Nature of Image in Digital Imaging

A digital image is composed of structurally ordered areas known as pixels. A pixel would be the digital equivalent of a silver halide crystals on conventional film. The difference is that silver halide crystals are randomly positioned in the emulsion whereas the pixel has a definite location that can be assigned a number (digit). The pixel is a single dot in a digital image and the image is formed by all of the pixels or dots on the image. Thus the image is composed of multiple dots with varying degrees of black and white. The pixel also has a gray

level that represents the photon penetration of the object (tooth) in that area.

In a computer the pixel is represented by a number that indicates its location and the photon penetration. The image on computer can be manipulated (added, subtracted).

The numbers in the pixel vary from 0 to 256 gray levels in an image. The human eye can only discern 32 gray levels. In diagnosis we rely on contrast discrimination (gray levels) rather than spatial relations and definition. The disadvantage of digital imaging is that digital images have only 9 to 10 line pairs per millimeter discrimination as compared to 15 line pairs per millimeter required for film.

Once the image appears on the screen a number of different software 'Enhancements' can be applied.

In the Second Technique (PSP Technique)

The imaging plate (sensor) is thinner and more flexible and is not attached to the computer. After exposure is made, a plate is inserted into machine that scan it with a laser, converting the latent image into a visual image on the computer screen. This process takes 30 seconds to 2.5 minutes.

Intraoral and panoramic radiography can be done with CCD and PSP digital imaging systems.

In this system the IOP film and panoramic cassette are replaced by the digital sensor.

Digital Subtraction

Used for evaluating changes in bone height and for density in periodontities and the degree of healing and remineralization of periapical lesions after endodontic therapy.

Thus the subtraction technique gives a study of changes overtime any lesion such as bone cysts and tumors.

The subtraction technique is more feasible for intraoral views for evaluating changes in small lesions but not very effective on panoramic imaging.

Advantages of Digital Radiography

1. Indicated in the detection of dental caries, periodontal diseases and periapical lesions.
2. Reduced radiation exposure.
3. Reduced time of image acquisition (image is produced within seconds).
4. Ability to transmit images electronically.
5. Ability to be used with a number of image analysis tools.
6. Enhancements of contrast (contrast can be raised or lowered to create a better image) and brightness.
7. The measurement tool can determine the dimensions of a lesion.
8. Availability of digital subtraction.
9. Bone loss and bone gain can be portrayed as red and green respectively in the program.
10. There is requirement in dental office with no more chemicals, developer, pollution, film or problem of light exposure.
11. The image in the monitor can be enlarged and transmitted via modem to an insurance company or a specialist, so easier communication to the outside world.
12. The image can be colored and filtered to bring out greater detail to enhance diagnosis.
13. Users can rotate images, take measurements directly on the screen and add written notes to be stored with the image.

Disadvantages of Digital Radiography

1. Relatively high-cost.

2. Resolution of fine structures of the head and neck may be less than optimal. (This can be removed by super high resolution ortho CT.)
3. If the patient has metallic restorations, these restorations produce artifacts that may observe as portions of the anatomy.

Uses

1. It is used for evaluation, extent of lesions, etc.
2. In trauma case, the degree of involvement of maxillofacial regions.
3. The paranasal sinuses, its condition and integrity.
4. The quality and quantity of bone in proposed dental implant sites.

CT is rarely indicated for evaluation of the TMJ.

For bony structures of TMJ conventional tomography or panoramic.

For disk displacement and other joint soft tissue by MRI.

CT is indicated in case of ankylosis or severe joint destruction or in case of silicon - sheeting TMJ implants.

CONVENTIONAL RADIOGRAPHY

Production of X-ray

X-rays are part of the electromagnetic radiation. They are used for all conventional radiography and computed tomography. Because of their short wavelength X-rays can penetrate materials, which do not transmit visible light. Their frequency and energy are much greater than visible light.

In X-ray tube high voltage electric current is passed across a vacuum tube between two terminals. One of the terminals, the cathode, is a tungsten alloy filament. The cathode is heated to liberate free electrons. When a high voltage in the range of 50-150 kV is applied across the two terminals, the electrons

are attracted toward the anode at high speed. They hit the tungsten target and X-rays are produced. They are able to pass through a patient and on to X-ray film thus producing an image, X-rays turns film black. The less dense a material the more X-rays get through and the blacker the film, i.e. materials of low density appear darker than subjects of high density. An object can be visible on conventional radiograph if its border lies besides tissue of density.

Projections in Conventional Radiography

Projection are usually described by the path of the X-ray beam. Thus a posteroanterior (PA) view is where the X-ray beam passes from the back to the front, which is the standard projection for a routine. An anteropostero (AP) view is one taken from the front.

CONVENTIONAL TOMOGRAPHY

Conventional tomography or sectional tomography may be used where an object is obscured or blurred by overlying or underlying structures.

The basic technique of tomography comprises movement of X-ray tube in one direction as against movement of film in the opposite direction. This will result in one particular part of plane of the object receiving the main concentration of the beam, because this part or plane will be superimposed on film for a longer time than other planes of the object (Fig. 19.2).

Several films can be taken at the same time by the use of the so-called multisection box. Thus multiple body section can be obtained with a single exposure.

COMPUTED TOMOGRAPHY

A new method of forming images from X-ray was developed and introduced into clinical practice by a British physicist

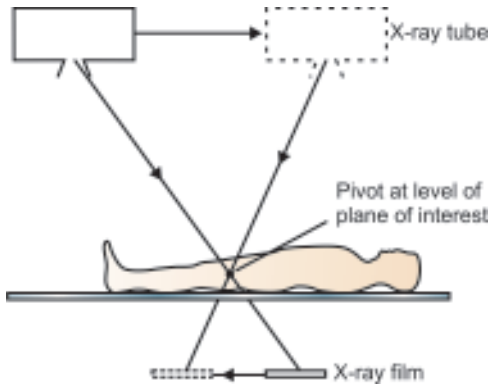


Fig. 19.2: Conventional tomography: The X-ray tube and X-ray film move about a pivot, the level of which is set at the desired plane of interest

Godfrey-Hounsfield in 1972. This is now usually referred to as computed tomography (CT) or computerized axial tomography (CAT) (Fig. 19.3).

Initially all scans were done in the axial plane. Now the images can be viewed in the coronal plane, sagittal plane and axial plane. Thus the 'A' has been dropped from CAT (Fig. 19.4) and (Fig. 19.5). Computed tomography differs from conventional radiography in that it uses a more sensitive X-ray detection system than photographic film, namely gas or crystal detectors, and then manipulates the data from the detectors using a computer. Both systems use X-rays generated much the same way. The X-ray tube rotates around the patient. In some systems detector also move, but in others they are arranged as a stationary ring around the patient.

Principle of Computed Tomography

The principle of CT scanning is that conventional X-ray films provide only a small proportion of the data theoretically

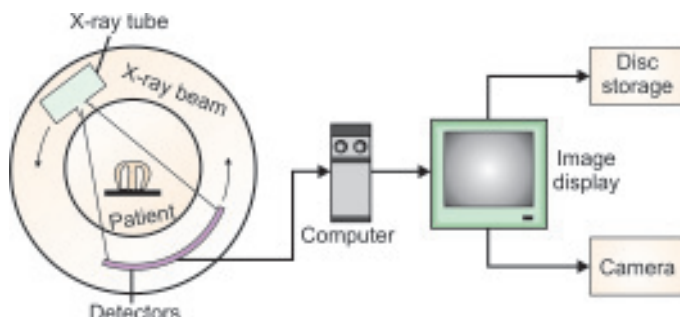


Fig. 19.3: Computed tomography—The method of forming images by CT

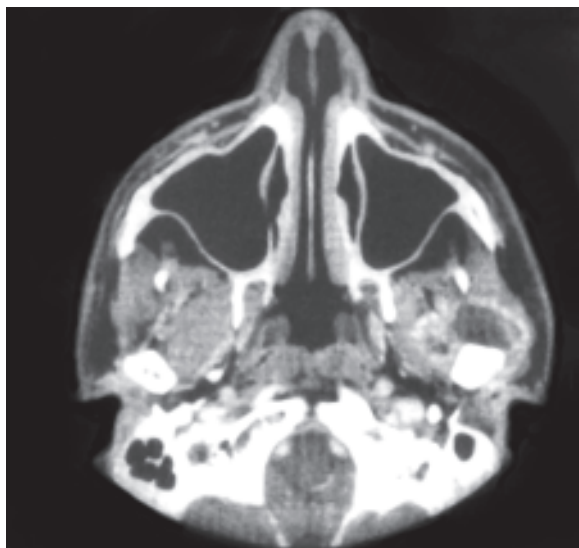


Fig. 19.4: CT scan in the axial plane. Note the gray soft tissue imaging and the radiopaque bone

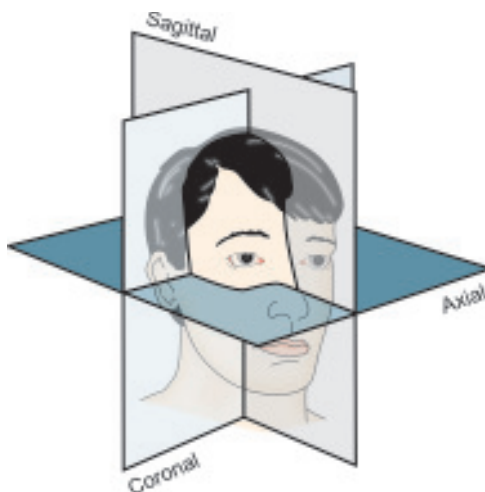


Fig. 19.5: All orientation planes

available when X-rays are passed through human tissues. By using multidirectional scanning of the object multiple data are collected concerning all tissues in the path of the X-ray beam. The X-rays fall not on the X-ray film but on to detectors which convert X-ray photons into scintillations. The detector response is directly related to the number of photons impinging on it and so to tissue density since more X-ray photons are absorbed by denser tissues. The detector send electric implses that are digitized and stored by the computer. This is called the scan.

Advantages of CT over Conventional Radiography

Its cross-sectional images allow internal structures to be visualized without superimposition and to detect much smaller difference in density. CT can determine density

differences of 0.5 percent or less and so it can better distinguish among fluid, soft tissues and fat.

Apart from its very high rate of diagnostic accuracy, CT is noninvasive and the radiation dose to the patient from a CT scan of the head is about the same as from a standard series of skull radiographs.

Most abnormalities are detected on CT by an alteration of normal attenuation (density) of a structure or by a change in size or contour.

Spiral (Helical) CT

CT scanners have now been developed which allow continuous acquisition of data as the patient passes through the gantry. This machine differs from conventional scanners in that the tube and detectors rotate without stops as the patient passes through as the scanning table. In this way, a volumetric set of data is obtained which has a helical configuration. The X-ray tube and detectors rotate on a number of slip rings, these are metal rings (Figs 19.6A to D).

The continuous volumetric nature of data allows accurate high-quality 3D reconstruction.

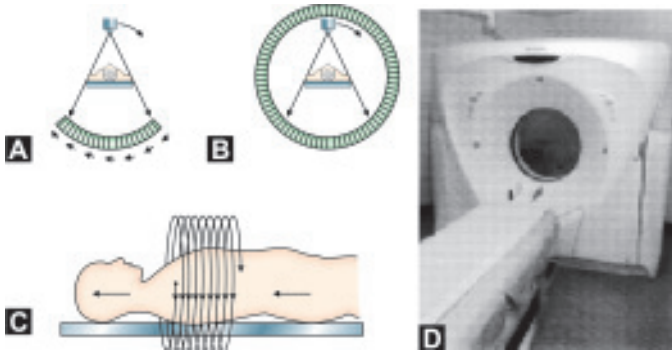
3D reconstruction techniques have many applications such as:

- Planning of cranial and facial reconstruction surgery.
- Repair of fractures in complex areas.
- CT angiography.

Advantages of Spiral (Helical) CT

Several advantages are associated with the use of spiral (helical) CT:

- The examination time is reduced by elimination of an interscan delay so that whole organs can be scanned on a single breath-hold.



Figs 19.6A to D: Diagrams showing the principles of (A) a third-generation CT scanner—both the X-ray tubehead and the detector rotate around the patient, (B) a fourth-generation CT scanner—the X-ray tubehead rotates within a stationary ring of detectors, (C) spiral CT—the tubehead and detectors move in a continuous spiral motion around the patient as the patient moves continuously into the gantry in the direction of the solid arrows and (D) The Philips MX 800 multislice spiral CT scanner

- The potential for a gap between slices is removed because a volume of tissue is scanned rather than scans being obtained slice by slice.

Cone Beam Computed Tomography

This is a new technology to acquire a CT image by cone beam computed tomography. This technique involves the use of a round or rectangular cone-shaped X-ray beam on a dimensional X-ray sensor. This technology is specifically useful in dental and maxillofacial regions and has the advantage of using less radiation and requiring less time for image. During a scan lasting 20 seconds, the patient is only exposed to ionizing radiation for about 3.5 seconds. The overall dose has been

estimated to be in the order of 0.035 and 0.10 msv. The scanner series has 360 images which includes transaxial, axial and panoramic images. It is also known as digital volume tomography. Different designs of machines available ranging from panoramic unit type to a medical CT unit type.

The equipment has a cone shaped X-ray beam (rather than a flat fan-shaped beam employed in conventional CT) and a special detector (an image intensifier). This equipment rotates around the patient in approximately 20-40 seconds and in one cycle or scan, images a cylindrical or spherical volume (field of view). The patient remains stationary during whole scanning (Figs 19.7A to C). The field of view varies from one machine to another and for view maxillofacial skeleton 15 cm diameter cylinder or spherical shape is required to fit into the skeleton and imaged in one scan (Fig. 19.8). The computer then collates the information from one scan into tiny cubes or voxel ($0.4\text{ mm} \times 0.4\text{ mm} \times 0.4\text{ mm}$). Individual voxels (primary reconstruction) are much smaller than in medical CT. One scan usually contains over 100 million voxel. Computer manipulation (known as multiplanar reconstruction) of the data obtained allows separate images in the sagittal, coronal and axial plane to be created. Multiplanar reconstruction also allows arch to enable the computer to construct a panoramic image made up of the voxels which coincide with plotted arch shape (Figs 19.9A and B).

Indications

- For diagnosis of cysts, tumors, giant cell lesions.
- Investigation of maxillary antrum, TMJ, osseous dysplasias.
- Implant assessment.
- Orthodontic assessment.
- Views utilizing fracture of mandible and middle third facial selection.

**A****B****C**

Figs 19.7A to C: Examples of three cone beam CT machines specially designed for imaging the maxillofacial skeleton: (A) NewTom 3G (NIM S.r.l Italy), (B) I-CAT™ (Imaging Sciences International, Inc. USA), (C) Galileos (Sirona, Germany)

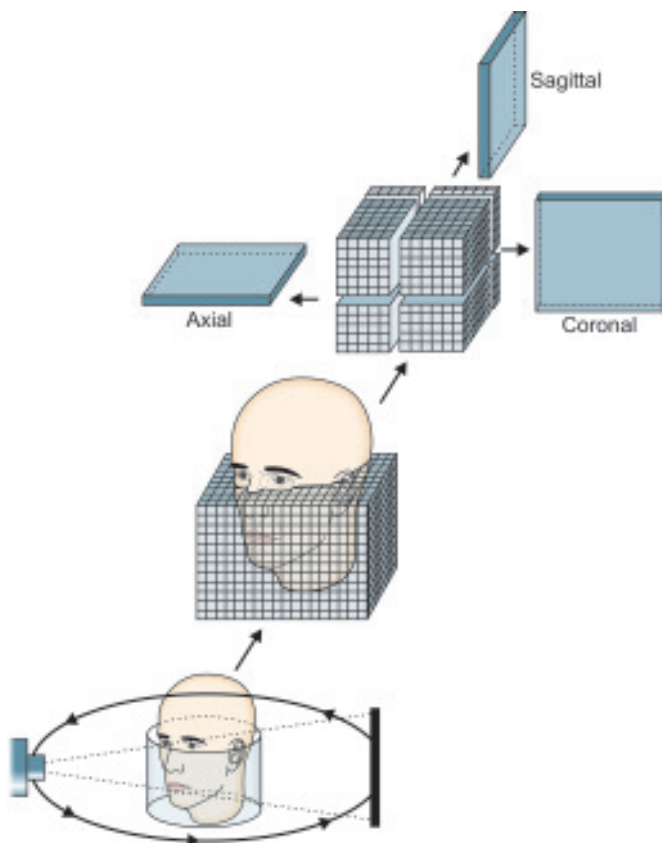
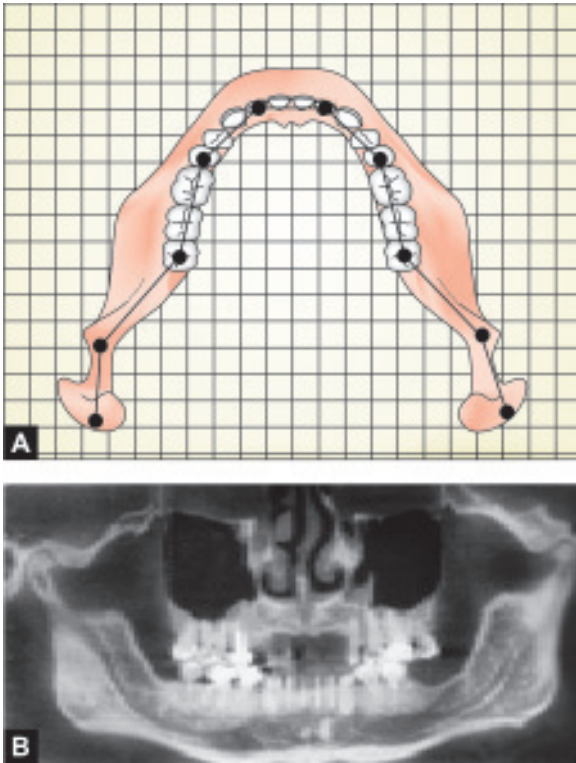


Fig. 19.8: Diagram showing the basic concept of cone beam CT. A cone-shaped X-ray beam is used which orbits once around the patient obtaining information in a cylindrical volume. The patient's maxillofacial skeleton is positioned within the cylinder and is divided into tiny cubes or voxels. Computer manipulation (multiplanar reconstruction) of the data obtained allows separate images in the sagittal, coronal and axial planes to be created



Figs 19.9A and B: (A) Diagram showing how plotting the shape of the arch, identifies the cubes/voxels that are required for the computer to generate a panoramic image. (B) An example of a computer-generated cone beam CT panoramic image

ULTRASOUND

Ultrasonic diagnosis employs sound waves whose frequency is far higher than can be registered by human ear. These ultrasonic waves are produced from a transducer and travel

through human tissues of a velocity of about 1500 meters per second. Very high frequency sound is directed into the body from a transducer placed in contact with the skin. As the sound travel through the body, it is reflected by the tissue interfaces to produce echoes which are picked up by the same transducer and converted into an electrical signal. This can be amplified and shown on a cathode-ray tube.

Principles of Ultrasound and Mechanism of Action

Ultrasonography is based on Piezo-electric effect. This effect is based on the fact that certain substances possess the quality of conversion of electrical to sound energy and vice versa. Transducers are substances that have the property of being able to convert one form of energy into another. Ultrasound transducers are made of materials that are mechanically deformed when an electric voltage is applied to them. This is the direct 'piezo-electric' effect.

Ultrasound is generated pulses from a transducer consisting of a disk of lead zirconate titanate which has piezo-electric properties. When a voltage is placed across the disk, it creates a pulse of high frequency sound waves. The interfaces of different body tissues pass through the body in straight lines and they are reflected and refracted at the interfaces between the various structures of the body. Strong reflections (echoes) are obtained at the interfaces between substances with differing transmission (acoustic) properties. The echoes consist of mechanical vibrations which are returned to the transducer disk and converted by it into electrical impulses. These impulses are amplified and is played on a cathode-ray oscilloscope or TV monitor and can then be photographed.

Ultrasound is the ideal technique for distinguishing between cysts and solid structures but is not always possible to distinguish between different fluids (e.g. blood, pus, ascitic

fluid). Of solid tumors, malignant ones usually have a weak heterogeneous echotexture whereas benign ones are usually homogeneous. A vascular tumor is often less echogenic than one which is less vascular.

Doppler Effect

Sound reflected from a mobile structure shows a variation in frequency which corresponds to the speed of movement of the structure. This shift in frequency, which can be converted to an audible signal, is the principle underlying the Doppler-probe.

The Doppler effect can also be used to image blood flowing through heart or blood vessels. Here the sound is reflected from the blood cells flowing in the vessels. If the blood is flowing toward the transducer, the received signal is of higher frequency. If the blood is flowing away the transducer, the received signal is of low frequency.

Colored Doppler is superimposition of Doppler information in color on a standard ultrasound image. The direction of blood flow can readily be determined and flow toward the transducer is by convention colored red, whereas blue indicates flow away from the transducer. This gives a better information by indicating color to the directing blood flow.

Advantages of Ultrasonography

- It is a relatively cheap diagnostic procedure and is easily available.
- It is a noninvasive technique.
- It does not involve the use of ionizing radiation, hence can be safely used in expected mothers for fetal monitoring.
- It can be used as frequently as needed for a follow-up study.

- Ultrasound guided biopsies using percutaneous needle drainage can be easily done for drainage of abscess or renal hepatic biopsies.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is the latest major addition to imaging technology. The basic principles of MRI depend on the fact that nuclei of certain elements behave like small, spinning bar magnets and align with the magnetic force when placed in a strong magnetic field (Fig. 19.10). At the field strengths currently used in medical imaging, hydrogen nuclei (protons) in water molecules and lipids are responsible for

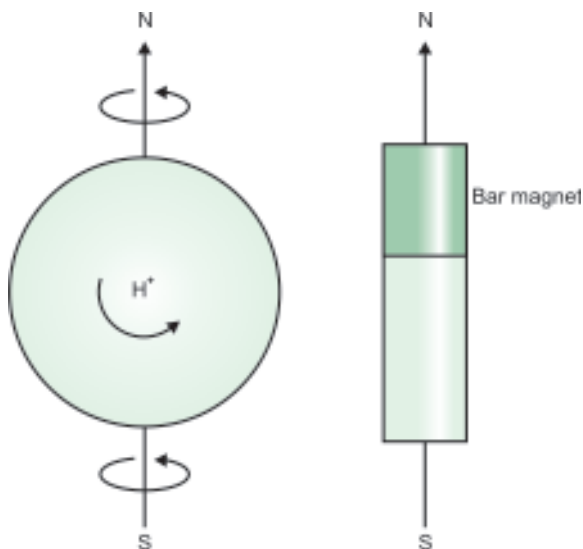
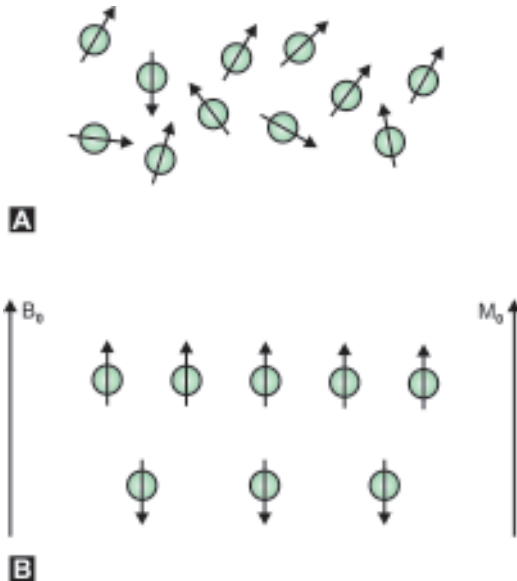


Fig. 19.10: The spinning hydrogen atom. The hydrogen atom being a spinning charged particle has a small magnetic field analogous to a bar magnet



Figs 19.11A and B: Effect of application of strong external magnetic field: (A) The hydrogen atoms are randomly aligned in the normal resting state. (B), A strong external magnetic field, B_0 , is applied. The atoms align either parallel or antiparallel to this field. The majority align parallel so their net magnetic vector, M_0 , is in the same direction as the external field, B_0 .

producing anatomical images (Figs 19.11A and B). If a radiofrequency pulse at an appropriate frequency (resonant frequency) is applied, a proportion of the protons change their alignment and rotate in phase with one another. The use of a strong external magnetic field will force a proportion of these protons to align in a new magnetic axis from their previous random orientation. The fields used in clinical practice range from 0.15 to 1.5 Tesla (1,500 to 15,000 Gauss) as compared with the earth's magnetic field of 0.5 Gauss.

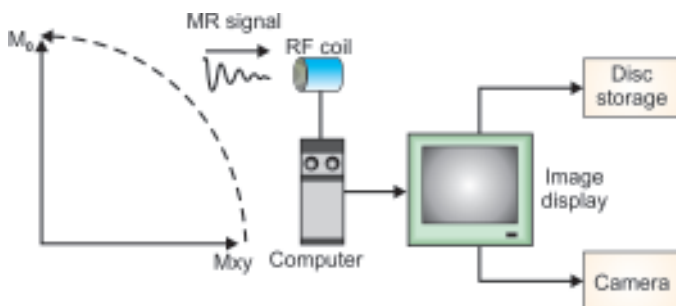


Fig. 19.12: Production of the MR signal. When the RF pulse is switched off, the net magnetization vector returns to its original direction and emits a signal that is received by the RF coil. This signal is analyzed by computer to produce an image

As the protons realign (relax), they induce a radiofrequency signal which, though very weak, can be detected by coils placed around the patient. The site of origin of this radio signal can be determined and an image representing the distribution of hydrogen protons can be build up (Fig. 19.12).

Advantages of MRI

- It is a noninvasive technique.
- It is safe as it does not involve the use of ionizing radiations.
- There is no adverse biological effect.
- Images can be readily produced in any plane, e.g. axial, sagittal or coronal without changing position of the patient.
- It gives high intrinsic contrast.

Disadvantages of MRI

- Very high cost of imaging.
- Inability to image bone and calcium.

- It is unsuitable for patients with cardiac pacemakers and other ferromagnetic implants.
- Imaging time is long; hence movement or motion artifacts are quite likely.
- Highly operator dependent, hence requires technical expertise.

SCINTIGRAPHY OR RADIONUCLIDE IMAGING (RADIOISOTOPE SCANNING)

Scintigraphy refers to the use of gamma radiation to form images following the injection of various radiopharmaceuticals. The key word to understanding scintigraphy is 'radiopharmaceutical'. 'Radio' refers to the radionuclide i.e. the emitter of gamma rays. The most commonly used radionuclide is technetium, i.e. ^{99m}Tc , where 99 is the atomic mass and the small 'm' stands for 'metastable'. Metastable means that the technetium atom has two basic energy states, high and low. When the technetium passes from the high-energy state to the low-energy state, it emits a packet of energy in the form of a gamma ray which has an energy of 140 keV (Fig. 19.13). The gamma rays are detected by a gamma

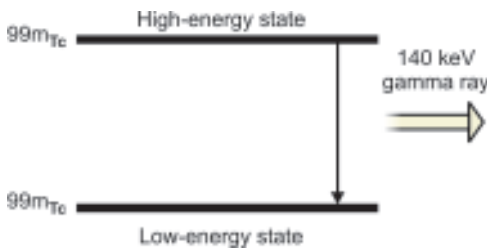


Fig. 19.13: Gamma ray production. The metastable atom ^{99m}Tc in passing from the high-energy state releases gamma radiation which has a peak energy of 140 keV. This makes it very suitable for use in imaging. ^{99m}Tc has a half life of about 6 hours

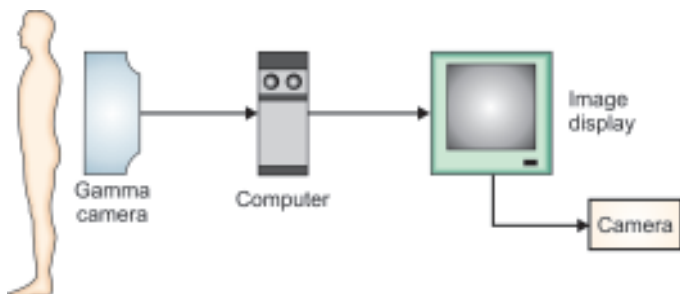


Fig. 19.14: Scintigraphy

camera that converts the absorbed energy of the radiation to an electric signal. This signal is analyzed by a computer and displayed as an image (Fig. 19.14).

Isotopes of an element are nuclides with same atomic number but with different mass number and often a different energy state, e.g. the isotopes of iodine are I^{123} , I^{125} and I^{131} . Radionuclides and radioisotopes are radioactive varieties but the terms in practice are interchangeable with nuclides and isotopes.

The radioisotopes used in medical diagnosis are artificially produced and most have short half lives, usually a few hours or days. To keep the radiation dose to the patient to a minimum, the smallest possible dose of an isotope with a short half life should be used. The radionuclide should be rapidly excreted from the body following completion of the investigation.

Principles of Radionuclide Imaging

Radionuclide imaging depends on the fact that certain substances concentrate selectively in different parts of the body. Radionuclides can be chemically tagged to these substances.

Radionuclide imaging relies upon altering the patient by making the tissues radioactive and the patient becoming the source of ionizing radiation. This is done by injecting certain radioactive compounds into the patient—that have an affinity for particular tissues, i.e. the target tissues. The radioactive compounds become concentrated in the target tissues and their radiation emissions are detected and imaged by a stationary gamma camera. This allows to examine the structure in static and dynamic conditions.

Indications in the Head and Neck Regions

- Tumor staging—the assessment of the sites and extent of bone metastases.
- Investigation of salivary gland function—especially in Sjögrens syndrome.
- Assessment of growth in condylar hyperplasia.
- Investigation of thyroid.
- Brain scans and assessment of a breakdown of the blood-brain barrier.

Advantages

- Investigation of target tissue function.
- The whole skeleton can be imaged during a bone scan.
- Availability of computer analysis and enhancement results.

Disadvantages

- Poor image resolution.
- The radiated dose is high.
- Difficulty in localizing exact anatomical site of source of emissions.
- Time consuming for some investigations.



19.15: A photograph of radionuclide technetium

The radionuclide technetium-99m (^{99m}Tc) is readily prepared has a half life of $6\frac{1}{2}$ hours and emits gamma radiations. Other radionuclides that are used include indium-111 gallium-67, iodine-123 and thallium-201.

The gamma rays emitted by the isotope are detected by a gamma camera consists of a circular sodium iodide.

Technetium-99m can be used in ionic form (as pertechnetate) for salivary gland, blood, liver, lung and heart, thyroid and vascular imaging, or organic phosphate labeled with ^{99m}Tc will be taken up by the bones and can be used to visualize the skeleton (Fig. 19.15).

- Gallium (^{67}Ga)—used for tumors and inflammation.
- Iodine (^{123}I)—used for thyroid.
- Krypton (^{81}Kr)—used for lung.

In the individual organ, lesions, such as tumors, may take up selectively more of the isotope, resulting in the so-called 'hot' areas on the scan, as in the brain. Alternatively, they may fail to take up the isotope resulting in 'cold' areas, as in the liver. The uptake can be recorded as images by scanners.

This view is used to visualize all the paranasal sinus, i.e. maxillary, frontal and ethmoidal sinus hence this view is also known as paranasal view. If the patient's mouth is open, the sphenoidal sinus may also be achieved. This projection is also useful to view facial bones, zygomatic arches, zygomatic complex and orbital floors and is used to evaluate traumatic injuries to these areas.

CONTRAST STUDIES

This study uses the contrast media, which is the radiopaque substance that has been developed to alter artificially the density of different part of the patient after injecting into the tissue. By this it alters the subject contrast, i.e. the difference in the X-ray beam transmitted through different parts of the patient's tissues. By the method, the structures and tissues which are invisible by conventional means can be seen. The different methods of contrast studies for the tissues are:

- Sialography – Salivary glands
- Arthrography – Joints (TMJ)
- Angiography – Blood vessels
- Lymphography – Lymph nodes and vessels
- Urography – Kidneys
- Barium meal – GI tract
- Computed tomography

Types of Contrast Media

1. **Iodine**-based aqueous solutions used for all investigations. This is divided into—

- (a) *Ionic monomers:*
 - Iothalmate (e.g. conray)
 - Metrizole (e.g. isopaque)
 - Diatrizole (e.g. urografin)
- (b) *Ionic dimmers:*
 - Ioxaglate (e.g. Hexabrix)
- (c) *Nonionic monomers:*
 - Iopamidol (e.g. niopam)
 - Iohexol (e.g. omnipaque)
 - Iopromide (e.g. ultravist).
- 2. *Iodine base oil solutions:*
 - Lipiodol
- 3. *Barium sulphate for GI tract.*
- 4. *MRI contrast agent:*
 - Gadoliniums for magnetic resonance angiography.

Hazards of Contrast Media

The iodine-based aqueous solution have a small risk associated with their use, when they are introduced into the blood stream. Immediate generalized reactions are present classified as anaphylactoid though more recent work suggests an IgE mechanism is involved in a number of severe reactions clinically these reactions are similar to anaphylaxis reactions. Chemotoxicity and osmolality (osmotic pressure of the solution) and anxiety may also be the causes of complications.

Complications

The main complications associated with contrast media can be divided into—

1. *Mild reaction:*
 - Rash, flushing
 - Rhinitis, cough
 - Mild urticaria, pruritis
 - Headache, nausea, constipation

2. *Moderate reaction:*

- Vomiting, gastrointestinal cramps
- Bronchospasm, pulmonary edema
- Hypotension

3. *Severe reaction:*

- Cardiac arrhythmias, cardiac arrest
- Convulsions
- Anaphylactic shock and pulmonary edema

4. *Fatal:*

Prophylactic measures to minimize complications:

- Reassurance to the patient to reduce levels of anxiety
- Use of nonionic low osmolality contrast agents
- Skin test

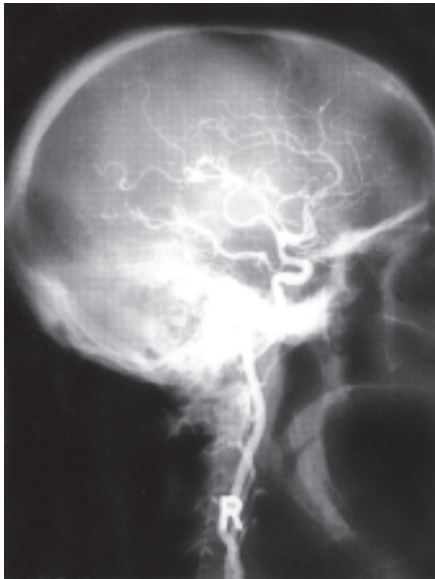


Fig. 19.16: Radiographer contrast media in the branches of the right internal radiograph following a barium meal

- Prophylactic oral or parenteral antihistamines (Diphenhydramine)
- Prophylactic steroids (Prednisone 50 mg)
- Cease or replace beta-blocker medication

Angiography

In angiography the aqueous iodine based contrast media is introduced into selected blood vessels. In the head and neck region, this involves usually the common, internal or external carotids or the vertebral arteries.

Usually the procedure is to introduce a catheter into a femoral artery followed by selective catheterization of the carotid or vertebral arteries, as required, by using fluoroscopic control. The contrast media is injected after seeing the catheter in the correct site, the radiographs of the appropriate area is taken (Fig. 19.16).

Chapter 20

Benign and Malignant Tumors of the Jaw

A diagnosis of any pathological lesion require:

1. Clinical
2. Radiological
3. Histopathological
4. Laboratory data

Radiographic evaluation of tumor is important to detect:

- (a) Type of tumor
- (b) Provide a specific diagnosis

In radiograph you see:

- (a) Radio density—radiopaque, radiolucent
- (b) Location
- (c) Three dimensional anatomic relationship
- (d) Architecture of the tumor tissue
- (e) Effect of the lesion on tooth, cortex, periosteum, nerve, vessel.

BENIGN TUMOR

A benign tumor is a new growth resembling the tissue of origin.

Characteristics

- (a) An insidious onset
- (b) Slow growth
- (c) A well-defined mass of regular and smooth outline
- (d) A fibrous capsule
- (e) Displacement of the adjacent normal tissues
- (f) Usually painless

Difference between Benign and Malignant Tumor

<i>Benign</i>	<i>Malignant</i>
(A) Expansion:	
1. Lesion borders have well-defined borders. A sharp demarcation between the destruction produced by the lesion and the normal appearance of the adjacent structures	1. Ill-defined borders, margins are irregular and ragged
2. Round or oval	2. Irregular evidence of new bone formation
3. No secondary infection present	3. Secondary infection causing changes induced by the tumor. Acute infections cause radiolucent bone destruction whereas a chronic process causes sclerosing osteitis in the bone
(B) Cortical bone:	
4. It causes expansion of the cortex. The tumor elevates the periosteum, it may cause formation of reaction bone, termed 'onion skin'. It grew by distention of bone	4. It grew by invasion and destruction of adjacent structures. It causes destruction rather than expansion of bone causing a 'sun burst' appearance
(C) Radio density:	
5. Radiolucent/radiopaque	5. Radiolucent lesion, the presence of new bone formation usually indicates the sarcoma rather than carcinoma
(D) Dental involvement:	
6. It expands around the root of teeth, leaving roots intact and the teeth in position.	6. More likely to cause resorption of teeth and displacement of roots.

TORUS PALATINES

In occlusal radiographs it appears as a dense radiopaque boarder of compact bone lies below and attached to the hard palate. It may be superimposed on the apical areas of maxillary teeth in IOP X-ray.

TORUS MANDIBULARIS

In occlusal radiographs it appears as a radiopaque, homogenous; knobby which protrudes from the lingual surface of the mandible.

In IOP radiographs shadow lies over about three teeth may be premolars and molars.

AMELOBLASTOMA

Radiographic feature varies according to the stage of its development.

In Early Stage of Development

The lesion is well-defined radiolucency and indicates slow growth and monostotic. Usually it is multilocular but sometimes it is unilocular.

In Advanced Cases

Develop compartments in the bone separated by distinct septa in the radiolucent area. In some cases the number and arrangement of septa may give the areas an honeycomb (numerous small compartments) or soap bubble (large compartments of variable size) appearance.

Root Resorption

Ameloblastoma causes extensive root-resorption than is observed with other lesions.

Occlusal Radiographs

Expansion and thinning of the both cortical plates over the affected area, but a thin 'egg shell' of bone usually persists.

ODONTOMA

Compound Odontoma

Demonstrates a number of tooth-like structures.

Complex Odontoma

Well-defined radiolucent area containing an irregular mass of calcified tissue. The contents of these lesions are largely radiopaque.

The borders of both lesions are well defined but vary from smooth to irregular and may have a hyperstatic border.

Ameloblastic odontoma may be radiopaque and similar to a complex odontoma or may be mixed, radiolucent and radiopaque.

OSTEOMAS

Well-defined radiopaque mass associated with the mandible or a paranasal sinus.

The mandibular lesion may be exospheric, extending outward into adjacent soft tissue spaces observed in periapical, extraoral or panoramic X-rays.

Those composed of compact bone are uniformly radiopaque, those containing cancellous bone show evidence of internal trabecular structure.

CENTRAL HEMANGIOMAS

Appears as an osteolytic defect that may take many forms, especially in the mandible.

Usually multicystic have a soap bubble or honeycomb appearance that results from a fine trabeculations within the locules.

MALIGNANT TUMORS

<i>Sarcoma</i>	<i>Carcinoma</i>
Arises within the connective tissue	Arises within the epithelial tissue
Less common	More common
Occurs in young people	Occurs after the age of 40 years
Spreads by bloodstream or by local extension	Spreads by local extension
Rapidly growing	Slow growing
Causes irregular destruction of bone with indistinct margins	Same
Osteolytic or may cause radiopaque calcification	Osteolytic results in radiolucency

SQUAMOUS CELL CARCINOMA

It is a distinctive lesion cause erosion of the alveolar bone producing ill-defined, irregular margins, may occur along the entire bony border of the tumor or restricted to relatively small area.

The margins of squamous cell carcinoma are characteristically ill-defined and radiolucent, occasionally there is a radiopaque zone beyond the lesion margins or at its border.

A radiograph may demonstrates the elevated outline of the soft tissue margins of the tumor above the lesions when the lesion extends to the internal border of the mandible. A pathological fracture is likely.

METASTATIC CARCINOMA

Same as a primary carcinoma, radiological lesion with ill-defined destructive margins may be single or multiple and vary in size.

When the metastatic lesion occurs in the alveolar bone; it may cause loss of the lamina dura leading to mobility or loss of teeth.

OSTEOSARCOMA

It arises from undifferentiated bone forming mesenchymal tissue. Various types of radiographic appearance.

Earlier Sign

A widening of the periodontal ligament space or radiolucency around one or more teeth.

Enlarged Tumor (Three Forms)

1. An osteolytic radiolucence appearance.
2. A radiopaque osteoblastic form.
3. A mixed radiolucent image with radiopaque foci.

Lesion is incentric and the borders are ill-defined.

Lytic variety has ragged border similar to carcinoma. Radiopaque show obliteration of previous trabecular pattern by new bone.

Mixed form shows perforation and extension of cortical margins.

As the tumor grows through the cortex, it elevates the periosteum and may cause the deposition of new bone. This new bone may be apparent in the form of spicules growing at right angles to the bone surfaces with a 'sun ray' appearance.

MALIGNANT MELANOMA

It appears a multiple small well-defined radiolucencies without a sclerotic border, producing the impression of 'punched out defect'.

Occasionally the border of these lesions display a thin sclerotic skin and even areas of bone have been reported.

Skull radiographs should be obtained for the diagnosis of the lesion.

Chapter 21

Diseases of Bone

FIBRO-OSSEOUS LESIONS

Fibro-osseous lesions represent a diverse group of pathologic conditions that are characterized by the replacement of normal bone with benign fibrous tissue containing different amount of (calcified) mineralized material and are difficult to classify and treat. Although these diseases have developmental, reactive and neoplastic etiologies, they all behave in a benign fashion. There are no universally accepted criteria to distinguish these lesions from one another either clinically, radiographically or histopathologically.

These lesions can be divided into two main groups—

- a. Fibrous dysplasia, a developmental lesion due to idiopathic arrest in the normal maturation of bone at the woven bone stage.
- b. Those lesion that originate from periodontal ligament, e.g.
 - Central cementifying fibroma (ossifying fibroma)
 - Periapical focal or florid
 - Osteomas
 - Giant cell lesions (central giant cell granuloma)
 - Osteoblastomas
 - Cherubism
 - Aneurysmal bone cyst

Fibrous Dysplasia

Fibrous dysplasia is an idiopathic disorder in which there is an arrest of primitive fibrous stroma at the woven bone stage such that the normal replacement of immature woven bone by lamellar bone does not occur. The medullary bone is replaced by poorly organized and loosely woven bone, which appears in the radiograph as obliteration of the medullary canal of involved bone associated with bone expansion and thinning of the overlying cortex.

This disease presents as asymptomatic, slow enlargement of the involved bone. It may involve one bone (monostotic 70%) or several bones concomitantly (polyostotic 30%). Polyostotic fibrous dysplasia may be associated with McCune-Albright Syndrome, cutaneous melanotic pigmentations (café-au-lait macules) and endocrine abnormalities.

Monostotic fibrous dysplasia is much more common than the polyostotic form. The most frequently involved sites are ribs, long bones, pelvis, jaws and skull. Fibrous dysplasia occurs in the maxilla more frequently than in the mandible. Maxillary lesions may extend to include the maxillary sinus, floor of orbit, zygoma and sphenoid bone. In some of the cases, lesions of fibrous dysplasia may pursue a more aggressive course, producing rapid growth, pain, nasal obstruction or enophthalmous (involving the floor of orbit). Rarely it is not evident until later in life due to insidious, asymptomatic nature of the lesion.

Radiographic Appearance

The classic 'ground glass' or 'frosted glass' appearance of fibrous dysplasia which appears in plain radiographs and CT is due to homogenous radiopacity by the myriad dispersed minute spicules of bone within the lesion, which is not encapsulated and blends into normal cortical bone. This gives an important distinguishing feature of fibrous dysplasia as poorly defined clinical and radiographic margins without evidence of a circumscribed border (Fig. 21.1).

The plain radiographic features have been classified into three patterns pagetoid (56%), sclerotic (23%) and radiolucent or cystic (21%).

The pagetoid patterns appear radiographically similar to the paget's disease having radiolucency with patchy, irregular opacities, resulting in a mottled radiographic appearance.

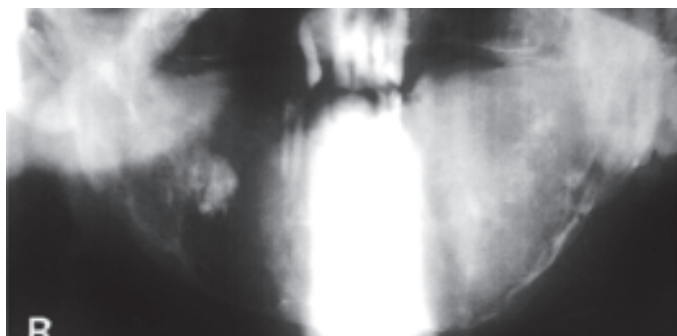


Fig. 21.1: Radiographic appearance of monostotic fibrous dysplasia

Fibrous dysplasia is typically hypointense on T1-, weighted MR images and of variable signal intensity on T2-weighted images, ranging from low to intermediate to high.

Central Cementifying Fibroma

Lesions (Central Cemento-ossifying fibroma) consisting stroma primarily of osteoid tissue, the lesion is ossifying fibromas and if the lesions with connective tissue stroma containing primarily foci of basophilic masses of cementum-like tissue are termed as cementifying fibromas and the lesion with a combination of osteoid and cementum-like tissue within the stroma are known as cemento-ossifying fibromas.

Central cemento-ossifying fibromas occur commonly in the facial bones, more in the mandible especially in molar/premolar area with a female predominance (5:1). These occur mostly in older age group (the third and fourth decades) and are more invasive than fibrous dysplasia. There are two important characteristics present is central cementifying osseous fibroma, first most of the disorganized bony spicules are composed of lamellar bone and second the osteoblasts run the trabeculae.

In CT, it appears as well circumscribed expansile, unilocular lesions with discrete areas of calcification and ossification.

Juvenile central cementifying osseous fibromas are aggressive, present in childhood at the age of 15 years at maxilla is more commonly involved than mandible, exhibiting rapid growth.

Radiographically, tumors present as a destructive expansile lesion often with well demarcated, even corticated borders. The lesion exhibits a primarily radiolucent quality with varying amounts of radiopacity, reflecting the degree of mineralization.

The ossifying fibroma is the well circumscribed, sharply defined border between the lesion and the adjacent normal bone.

The radiographic appearance is variable, depending on the degree of maturation and the amount of mineralization present. Early lesions present as unilocular or multilocular radiolucencies. The radiolucent stage gradually progresses to a mixed radiolucent-radiopaque stage as matrix material is deposited and mineralized in the lesions. Long-standing, matured lesions appear as dense, radiopaque masses surrounded by a thin, well defined, regular, radiolucent rim. The lesions may displace adjacent teeth and causes resorption of roots less commonly (Fig. 21.2).

Giant Cell Lesions

Central giant cell granuloma and central giant cell tumors are regarded as two different entity, but there are only gradual differences and no absolute criteria for differentiation. The term central giant cell lesion has recently been proposed.

The lesion typically produces expansion or swelling of the affected jaw and patient come to attention on incidental routine radiographic examination as radiolucent appearance of the lesion.

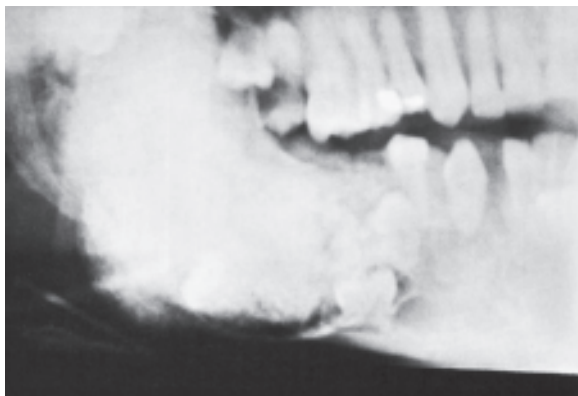


Fig. 21.2: Typical radiographic picture of an ossifying fibroma showing well-demarcated radiolucent mixed radiopaque mass

It is an uncommon, non-neoplastic fibro-osseous lesion with 7% occurrence to all benign jaw lesions. It is almost exclusively found in mandible and maxilla especially in the anterior mandible often crosses the mandible. It occurs more frequently in young adults and more common in female.

The radiographic feature of central giant cell granuloma consists of a multilocular or less frequently unilocular radiolucency of bone. The margins of the lesions are relatively well demarcated often presenting a scalloped border. Although well defined, a sclerotic border may be absent. Expansion and thinning of cortices are often noted with perforation and extension into soft tissues which is evident in some aggressive lesions (Fig. 21.3).

In CT this lesion gives the some two distinct patterns—a unilocular osteolytic lesion or multilocular with septations coursing through the lesion. The MR imaging features are relatively nonspecific and less deformation from other benign lesions of jaw such as Langerhans histiocytosis.

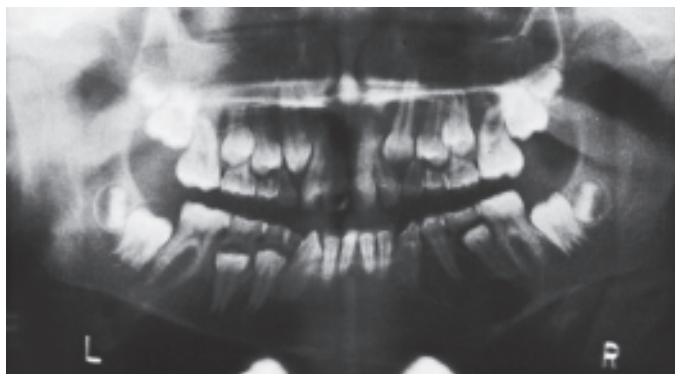


Fig. 21.3: Radiographic appearance of central giant cell granuloma

Osteomas

An exophytic nodular growth of dense cortical bone on the surface of or within the mandible or maxilla in locations different from those occupied by prior exosteoses.

Osteomas are well-differentiated benign tumors consisting predominantly of cancellons or compact bone that increase in size by continuous formation of bone (Fig. 21.4). These lesions are most commonly found within or on the periphery of membranous bones of the skull, face and jaws. The pathogenesis is obscure but a combination of trauma and muscle friction has been proposed. The lesion is more common in mandible. In Gardner's syndrome multiple osteomas may be encountered. The lesions are very slow growing, asymptomatic and are identified after the age of 25 years.

Cherubism

Cherubism is an inherited abnormal dominant disorder affecting the jaws characterized by the replacement of normal bone by a proliferation of fibrovascular tissue containing

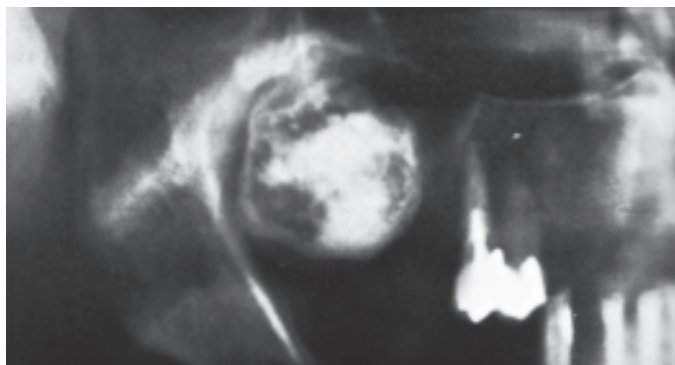


Fig. 21.4: Radiographic appearance of multilocular intraosseous radiolucencies of osteoma

multinucleated giant cells. The lesion develops as bilateral, symmetrical expansion of the affected bone, causing facial fullness. More common in male than in female, ratio is 2:1.

Cherubism usually manifests during childhood with the clinical manifestations of mild painless, bilateral, posterior mandibular expansion to generalized swelling affecting both mandible and maxilla. The developing permanent teeth in the areas of involvement are usually displaced, malformed or absent, regional lymphadenopathy is a common finding in cherubism.

The cherubism produced well defined multilocular radiolucencies of the affected portions of the jaws due to its osteolytic and expansile nature. Unilocular radiolucencies may be evident less commonly. As the lesions progress, they produce expansions and thinning of cortical bone. Perforation may be noted occasionally, displaced and malformed teeth may be evident within the multilocular radiolucent lesions (Fig. 21.5).

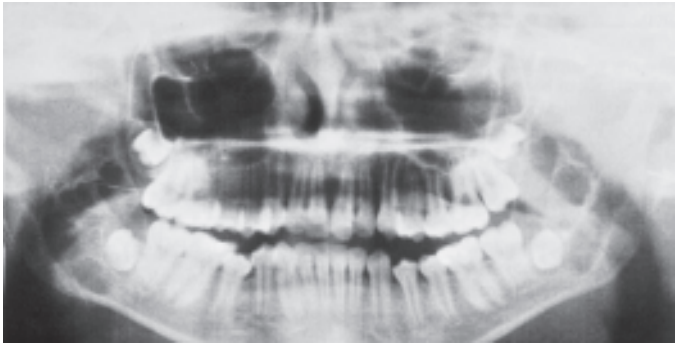


Fig. 21.5: Panoramic radiographic appearance of multilocular intraosseous radiolucencies of cherubism

Aneurysmal Bone Cyst

Aneurysmal bone cyst is relatively uncommon bone lesion that may affect any bone in the skeleton. Aneurysmal bone cyst may develop as a primary disease process or as a secondary lesion in the area of a pre-existing bone lesion. Bone lesions that are associated with the secondary development of aneurysmal bone cysts include fibrous dysplasia, ossifying fibroma, central giant cell granuloma, osteoblastoma and osteosarcoma. Trauma to the bone or the bony lesions causing reactionary capillary pressure from the extravascular blood produces the expansile, destructive aneurysmal bone cyst.

The lesion occurs in patients younger than 30 years of age, peak incidence in the second decade of life. Mandible being affected more commonly than maxilla, mostly in posterior region. They present as rapidly growing expansion of the affected bone.

The aneurysmal bone cyst produces a unilocular or multilocular radiolucency due to osteolytic nature. The lesion typically expands and thins the adjacent central bone. A characteristic radiographic feature has been described as a

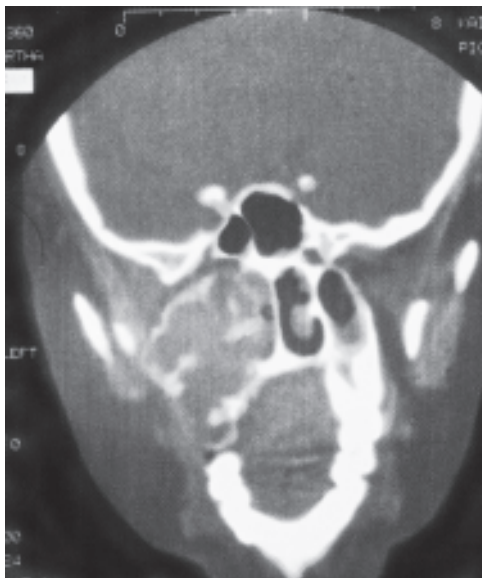


Fig. 21.6: Radiographic appearance of large multilocular radiolucency of aneurysmal bone cyst in CT scan

ballooning, distension of periosteum with a thin outline of reactive subperiosteal bone (Fig. 21.6).

Other Benign Tumors of Jaw

Osteoblastoma

These lesions are closely related to osteoid osteoma. Osteoblastoma represents as an unusual reactive process in bone.

Osteoblastoma rarely affects the craniofacial bones, the mandible is the most frequent site in the head and neck. The posterior areas of jaws are the usual sites of occurrence although condyle and coronoid processes are only rarely

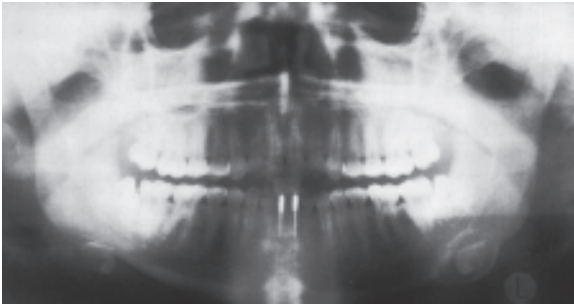


Fig. 21.7: A well-demarcated mixed radiolucent, radiopaque osteoblastoma at the angle of mandible

affected. Osteoblastoma develops mostly before the age of 30 years, more in male than in female, the ratio is 2:1. Pain often quite severe is the most common presenting symptom.

The radiographic picture in most of the cases is well defined, round to ovoid, mixed radiolucent-radiopaque lesions. The degree of calcifications of the central tumor mass may be minimal, in which case the lesion is primarily radiolucent. When the amount of calcification is more extensive, the central opaque lesion is usually surrounded by a thin radiolucent rim. A 'Sun ray' pattern of new bone formation, as is present in various malignant bone tumors, may be evident in these lesions. This can be differentiated from osteoid osteoma by absence of sclerosis of perilesional bone (Fig. 21.7).

Osteochondroma (Osteocartilaginous Exostosis)

Osteochondroma are the most common benign tumors of bone, representing 35-50% of all benign bone tumors. In the craniofacial region, these lesions are rare, reported in the maxillary sinus, zygomatic arch and mandible. Mandibular osteochondroma are most commonly located on the coronoid

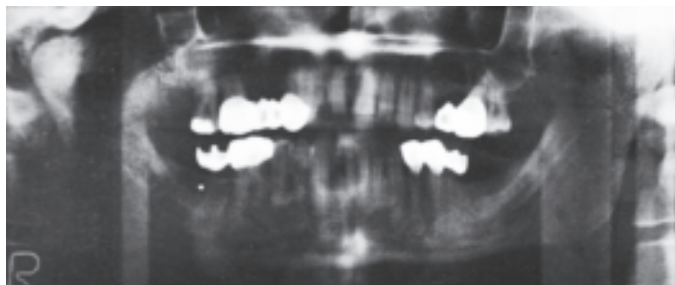


Fig. 21.8: A round radiopaque enlargement of condyle giving the picture of osteochondroma

process, followed by the condyle and also in ramus, body and symphyseal region. These exophytic lesions arise from the cortex of bone and are covered by a cartilaginous cap (Fig. 21.8).

Chondromas

Chondromas are benign tumors of cartilage, most chondromas occur in the hard palate and alveolar ridge or in the condyle or coronoid process of the mandible. Chondromas occur equally in both sexes, the mean age is 31 years.

MALIGNANT LESIONS

In all the oral cavity lesions, the malignant lesions account for only 7%, but of these lesions squamous cell carcinoma is about 90%. Other malignant lesions are adenoid cystic carcinoma, adenocarcinoma, mucoepidermoid carcinoma, lymphomas, sarcomas such as liposarcoma, rhabdomyosarcoma. The primary purpose of imaging these lesions is to detect their deep extent and involvement of adjacent structures.

Squamous Cell Carcinoma

Squamous cell carcinoma affects men aged about 40 to 70 years with a long history of alcohol and tobacco abuse. Heavy drinking smokers have a risk of developing squamous cell carcinoma 6 to 15 times greater than that of nonsmokers. Approximately two thirds of the tumors are moderately or far advanced at the time of initial presentation. The squamous cell carcinoma affects mostly the floor of the mouth, the ventro lateral surface of tongue and the soft plate, retramolar trigone and anterior tonsillar pillar. The causes of the occurrence at these sites due to floor of mouth and tongue are continuously bath in a pool of saliva, which may serve as a reservoir of exogenous carcinogens, primarily derived from the irritating effects of alcoholic beverages and tobacco. The carcinoma of the soft palate is due to inhaled tobacco smoke concentration in this area and exerts a direct carcinogenic effect.

CT and magnetic resonance imaging (MRI) both potentially better define the extent of tumor mass and the presence of clinically undiscovered lesions. MRI offers a more highly contrasted image than CT for soft tissue lesions. The T2-weighted MRI generally seems most sensitive for tumors below the surface. The most significant contributions of CT are its demonstration of primary lesion expansion and its obliteration of fully inter structural spaces. The use of contrast media gives a better picture of enhancement of large tumors and their loss of homogeneity. We know the fact that for most nonradiologists the CT films are easier to interpret than are MRIs.

CT can reliably produce neurovascular invasion by squamous cell carcinoma. Aggressive tumor margins, invasion of the sublingual space and lesion location adjacent to neurovascular structures are all highly suggestive findings of neurovascular invasion. All the cervical lymph node chains

should be imaged by either CT or MRI. MRI is not as accurate as CT in its ability to demonstrate either extranodal tumor spread or central neurosis.

MRI signal intensities are similar to those of muscle on T1-weighted. MR imaging appears to provide the most useful sequence for delineation of tumor margins and for assessing the extent of tumor.

Sarcomas

Osteosarcoma (Osteogenic Sarcoma)

Osteosarcoma is a tumor of malignant connective tissue cells directly producing osteoid and bone. It is the most common malignant tumor of bone and accounts about 20% of all sarcomas of the bone. The average age of onset is in the fourth decade. There is loosening and displacement of teeth, paresthesia, epistaxis and swelling without pain. The radiographic appearance of osteosarcoma of the jaws depends upon the interaction of three factors—destruction of bone, bone production and mineralization and new bone formation by the periosteum.

Lesions can appear as completely radiolucent, radiolucent with fluffy, cloudlike radiopaque areas or entirely radiopaque. The majority of tumors produce a mixed radiolucent radiopaque pattern with poorly defined, irregular borders. The tumor usually perforates the cortex and extends into soft tissue.

A 'Sunray' or 'Sunburst' radiographic pattern has been classically described for osteogenic sarcoma. It is produced when the periosteum forms spicules of bone perpendicular to its surface. This pattern occurs in the sarcoma of the jaw and is best visualized in occlusal radiographs (Fig. 21.9).

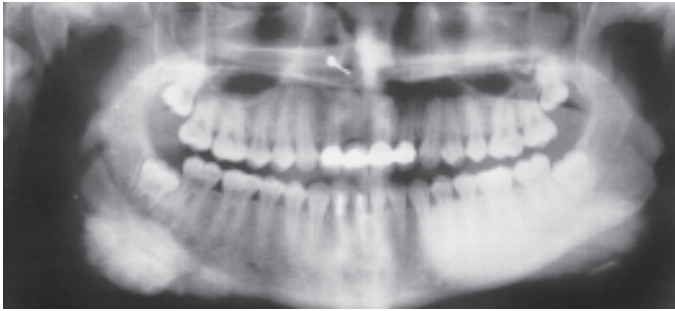


Fig. 21.9: Radiograph showing radiopacity and sunray appearance in osteosarcoma

Early osteogenic sarcoma of jaws have minimal radiographic changes.

In early stage there is symmetric widening of the periodontal ligament space around teeth in the area of the lesion. Destruction of the lamina dura and resorption of involved roots may also occur.

Chondrosarcoma

Chondrosarcoma is a malignant tumor of connective tissue origin in which tumor cells produce cartilage but not bone.

The radiographic appearance of chondrosarcoma of the jaws is variable. It can be radiolucent, radiolucent with radiopaque areas or diffusely radiopaque. Most commonly it presents as poorly defined radiolucent lesion with radiopaque foci resulting from mineralization or ossification of the cartilage matrix. Occasionally it causes symmetric widening of the periodontal ligament space and a sunburst pattern. It

can also infiltrate between trabecular of normal bone without significantly destroying bone. The intact trabecular bone has an essentially normal radiographic appearance even though the tumor can be extensive.

Multiple Myeloma

Multiple myeloma is a malignant proliferation of plasma cells arising within bone marrow.

The most characteristic radiographic appearance in multiple myeloma is multiple, sharply demarcated radiolucent lesions without corticated borders known as punched on the lesions (Fig. 21.10). Lesions are most common in bones with hematopoietic marrow, such as skull, pelvis,



Fig. 21.10: Radiograph showing radiopacity multifocal osteolytic lesions of the skull in multiple myeloma

proximal humerus and femur. Jaw involvement is reported in 12 to 30% of cases.

Ewings Sarcoma

Ewings sarcoma is a primary malignant tumor of bone that commonly involves the pelvis and lower extremities.

It appears radiographically as a radiolucent lesion with ragged, poorly defined margins. It may perforate the cortex of jawbone and have an associated overlying soft tissue mass (Fig. 21.11) .

Metastatic Tumors of the Jaws

The metastatic tumors are mostly carcinomas because of epithelial origins involving the jaws. The most common sites are breast, lung, prostate, kidney, bone and adrenal.

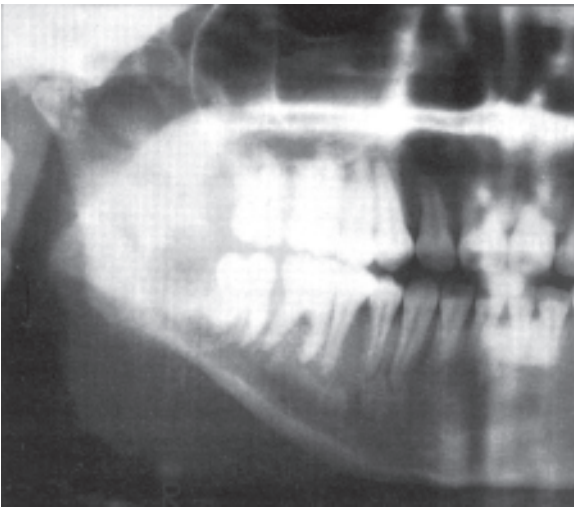


Fig. 21.11: Showing Ewing sarcoma of the mandible with destruction of bone

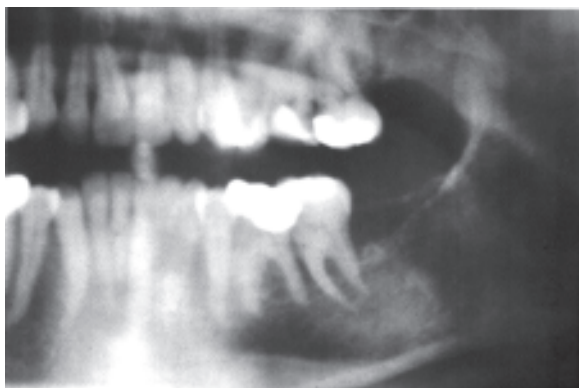


Fig. 21.12: Radiograph showing a large mixed radiolucent and radiopaque area in the posterior mandible (metastatic adenocarcinoma from breast)

Patients with metastatic tumors to the jaws experience enlargement of bone, pain, paresthesia and loosening of teeth.

Radiograph reveals a radiolucent lesion, typically with poorly defined or ragged borders. Occasionally lesion demonstrates circumscribed borders. Carcinomas of the breast, prostate and thyroid may be radiolucent, radiopaque or mixed (Fig. 21.12).

Chapter 22

Preoperative Radiographic Assessment of Impacted Mandibular Third Molars and Canines

Preoperative radiographic assessment of impacted mandibular third molar is important for performing surgery in orderly manner and to determine the difficulty of the extraction. The decision to operate by a suitable technique is guided by the radiographic assessment.

The radiographs required for preoperative assessment are:

- Intraoral periapical
- Panoramic radiographs
- Lateral oblique of mandible or bimaxillary
- Cone beam computed tomography (CT) (images in the coronal, axial and sagittal planes)

The radiographic assessment can be divided into the following headings:

- The surrounding bone
- The impacted third molar
- The mandibular second molar

ASSESSMENT OF THE SURROUNDING BONE

The main features which are required to examine are:

- The position of the external oblique ridge and the amount of bone surrounding the impacted third molar.
- The texture and density of the bone.
- Any previous pericoronitis.

If the angulation of external oblique ridge is vertical the access to the tooth is poor and if the external oblique ridge is horizontal the access to the impacted third molar is good. Normally, in radiograph, the external oblique ridge appears as a radiopaque line starting from the premolar area and curves upward and backward toward the ramus area.

If the marrow part of the bone is more and the trabeculae are smaller in diameter the bone is spongy and cutting of bone is easier. If the cortical part is more dense, i.e. the trabeculae are larger in diameter the bone is dense and difficult to cut.

Any previous pericoronal infection may result into a dense thick bone causing difficulty in cutting the bone. Sometimes a resorption of bone may be present surrounding the crown of the tooth by a previous pericoronal infection.

MANDIBULAR THIRD MOLAR ASSESSMENT

The main features which required to examine for assessment are:

1. Angulation
2. The crown
3. The roots
4. The relationship of the apex of the root with the inferior alveolar canal
5. The depth of the tooth in the alveolar bone
6. The buccal or lingual obliquity.

Angulation (Fig. 22.1)

According to Pell and Gregory classification the impacted third molar could be:

- Mesioangular
- Distoangular
- Horizontal
- Vertical
- Transverse
- Inverted

The Crown

The crown of the impacted third molar is examined in the following headings:

- The size—the size may be bulbous, large cusp or microdontia
- The shape—taurodontism

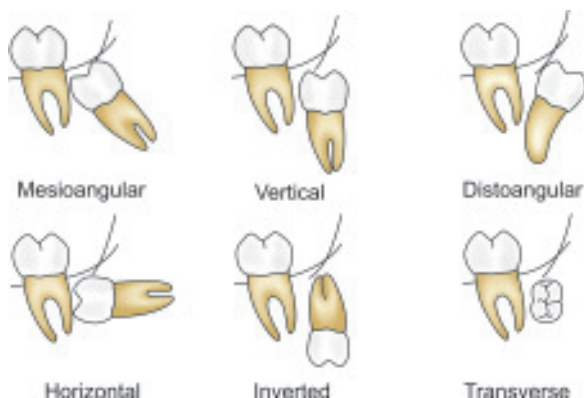


Fig. 22.1: Diagram showing the angulation of impacted mandibular third molar

- The presence and extent of caries
- The resorption of roots of third molar and assess the severity of resorption.

The Roots

The roots of the third molar is examined carefully because most of the time there is chances of fracture of apical portion of the root due to unfavorable curvature of root portion (Fig. 22.2).

This is assessed in the following heading:

- The number—single, double or triple roots or any extra root.
- The shape—conical shaped or pincer shaped.
- Curvatures—dilaceration present, favorable or unfavorable roots.
- Stage of development of root.

The most suitable age for extraction is when 1/3rd root has been formed and 2/3rd is going to be started, i.e. between the age of 16 and 18 years.

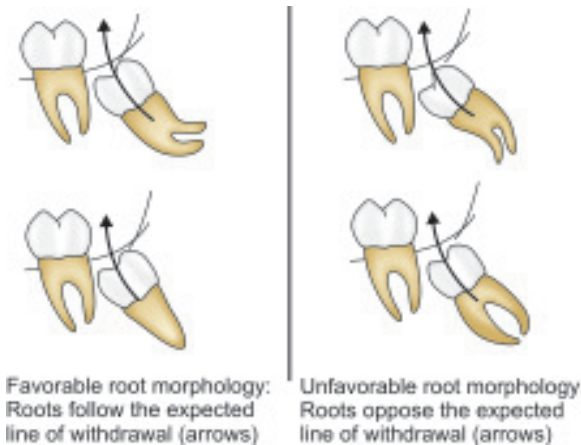


Fig. 22.2: Diagram showing favorable and unfavorable root curvature

The relationship of the apex of the root of the impacted mandibular third molar to the inferior alveolar canal:

The normal appearance of inferior alveolar canal is a radiolucent band which is surrounded by two thin parallel radiopaque lines (called tramlines).

The apices of the mandibular third molar often appear in close relationship to the inferior alveolar canal. This relationship is usually due to superimposition or grooving or even perforation of the root by the canal (Figs 22.3A and B).

The variation in the appearance of the canal in the radiographs can be:

- Loss of one or both tramlines.
- A radiolucent band evident across the root if the root is perforated or contains the inferior alveolar canal.
- A sudden change in the direction of the tramlines.

Generally, in most of the case, the inferior alveolar canal is present on the lingual side of the root of the mandibular

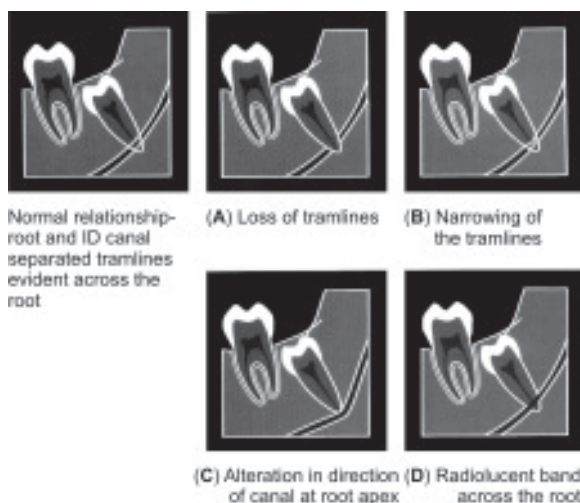


Fig. 22.3A: Diagram showing the relationship of the apex of mandibular third molar to inferior alveolar canal

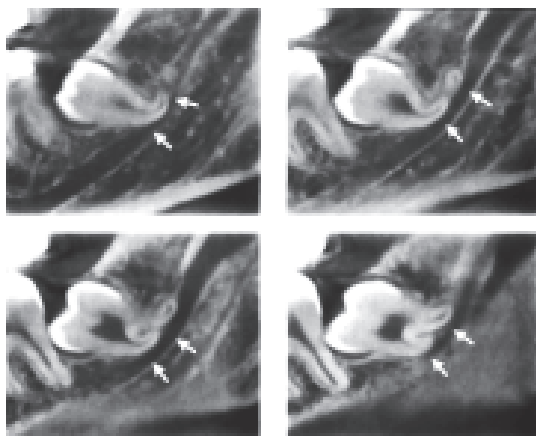


Fig. 22.3B: A series of four high-resolution 3DAccuitomoTM, cone beam CT images of 8 showing the relationship of the roots to the ID canal

third molar and if buccal approach is taken for extraction no injury to the nerve would result.

Depth of the Tooth in the Alveolar Bone

The depth of the mandibular third molar can be assessed by two methods:

- (a) Winter's WAR lines.
- (b) The roots of the second molar used as a guide.

Winter's WAR Lines

Winter described three imaginary lines which are drawn on a periapical radiographs. These lines are named according to the color as white, amber and red lines.

The first or white line is drawn along the occlusal surfaces of the erupted first and second molars and then extends up to the third molar.

The second or amber line is drawn along the crest of the interdental bone between the first and the second molars, extending distally along the internal oblique ridge, not the external oblique ridge. This line indicates the margin of the alveolar bone surrounding the tooth after elevation of the soft tissue flap (Fig. 22.4).

The third or red line is perpendicular dropped from the white line to the point of application for an elevator but is measured from the amber line to this point of application. This line measures the depth of the third mandibular molar within the mandible. If the red line is 5 mm or more in length the extraction is considered sufficiently difficult.

Roots of Second Molar is Used As a Guide

The roots of the adjacent second molar are divided horizontally into thirds—coronal $1/3$, middle $1/3$ and apical $1/3$ (Fig. 22.5).

A horizontal line is drawn from the point of application for an elevator to the second molar.

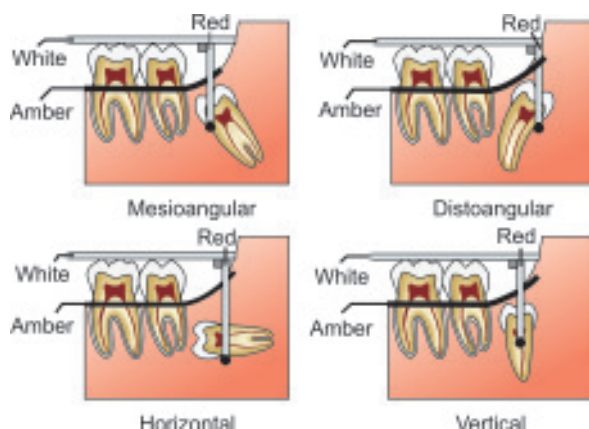


Fig. 22.4: Diagram showing Winter's WAR lines



Fig. 22.5: Diagram showing the relation of point of application of an elevator to the roots of the lower second molar to assess the depth of the third molar in the alveolar bone

If the point of application lies opposite the coronal, middle or apical third, the extraction is assessed to be easy, moderate or difficult, respectively.

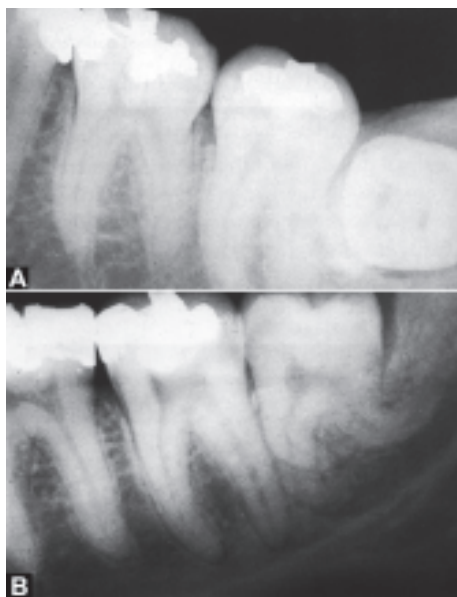
Buccal or Lingual Obliquity

The views required to assess the buccal or lingual obliquity include:

- Lower 90° occlusal
- Lower oblique occlusal

Buccal obliquity: The crown of the impacted tooth is inclined toward the cheek.

Lingual obliquity: The crown of the impacted tooth is inclined toward the tongue (Figs 22.6A and B).



Figs 22.6A and B: (A) Transversely positioned 8. The more radiopacity of crown indicated the lingual obliquity of the crown (B) Vertically positioned 8 with very unfavorable root curvature

Mandibular Second Molar Assessment

The second molar is assessed to decide the planning of the surgery to prevent the dislodgment of the second molar from the socket during the extraction of third molar.

The main features to examine are:

- The crown
- The roots.

The Crown

The following particulars should be noted:

- The shape of the crown—the large bulbous crown will interfere with the extraction of third molar.
- The shape—if it is conical more chances for dislodgment of the tooth.
- The periodontal status.
- The condition of the apical tissues.

The Roots

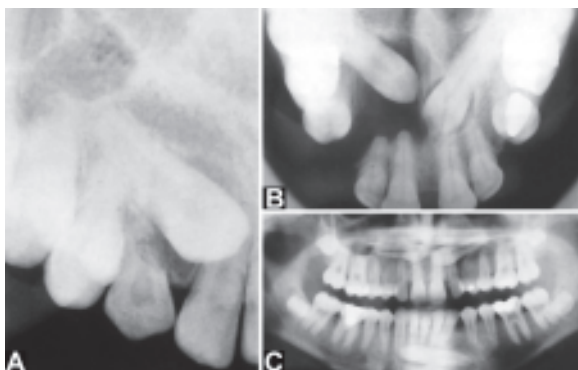
If the root of the second molar is single rooted, there is more chances of dislodgment of the second molar during the extraction of impacted third molar.

PREOPERATIVE RADIOGRAPHIC ASSESSMENT OF UNERUPTED MAXILLARY CANINES

The maxillary canines are often misplaced and fail to erupt into the dental arch due to their long path of eruption, the timing of their eruption and the discrepancy between the arch length and the total tooth size length.

The importance of preoperative radiographic assessment is:

- To determine the size and shape of the canine. In most of the cases the apex of the canine is dilacerated which results into fracture if not properly planned.



Figs 22.7A to C: (A) A periapical radiograph showing impacted canine. (B) An upper standard occlusal radiograph showing bilateral impacted canines. (C) Panoramic radiograph showing unerupted canine

- To determine the position of the canine.
- Any pathology in relation to the tooth or resorption of the adjacent lateral incisor.

Assessment of Size and Shape of the Canine

Radiographs which are used for this purpose are (Figs 22.7A to C):

- Intraoral periapical
- Upper standard occlusal radiograph
- Panoramic radiograph
- Lateral cephalometric view.

The specific features which are required for radiographic interpretation are:

- The crown
- The root
- Adjacent tooth and surrounding structures.

The Crown

The following particular are noted:

- Size
- Shape
- The presence of resorption and its severity
- The presence of any related pathology such as dentigerous cyst
- The effect on adjacent teeth such as resorption of lateral incisors.

The Root

The following particulars are noted:

- Size
- Shape—any dilacerations or hook-shaped apex
- Stage of development of root.

Assessment of Position of the Canine

The position of canine or other unerupted tooth or odontome is determined by taking different radiographs depending on available facilities. The most suitable method of localization of unerupted canine is by clark's (parallax) method.

The Principle of Parallax

Parallax is defined as the apparent displacement of an object because of different positions of the observer. This means, if two objects, in two separate planes, are viewed from two different positions, the objects will appear to move in different directions in relation to one another, from one view to the next (Fig. 22.8).

The periapical parallax (tube shift) X-ray technique is the standard for localization of unerupted tooth on the labial or palatal aspect of the arch. The first radiograph is taken in the standard fashion, with the X-ray beam perpendicular to the film. The second radiograph is taken with the film in the same position but the tube moved toward the side of the unerupted tooth. Based on the clark's rule, an unerupted tooth lying on

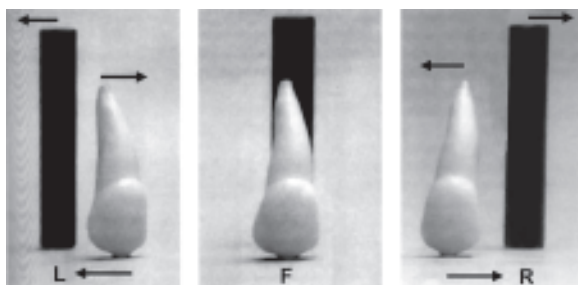


Fig. 22.8: The principle of parallax. Photographs of a small black cylinder positioned behind a tooth. From directly in front (F), the tooth and cylinder are superimposed. With the camera moved to the left (L), the tooth and cylinder are both visible and appear to have moved in different directions. The cylinder, being further away from the camera, appears to have moved in the same direction as the camera, i.e. to the left, while the tooth appears to have moved in the opposite direction. With the camera moved to the right (R) a similar apparent movement of the tooth and cylinder relative to the camera takes place, with the cylinder appearing to have moved to the right and the tooth to the left

the palatal side of the arch will move in the same direction as the X-ray beam, whereas one on the labial aspect will move in the opposite direction.

If the unerupted tooth is lying in the line of the arch, it will not change its location in the two radiographs.

The methods of localization of canine are:

- Parallax in the horizontal plane
- Parallax in the vertical plane
- Stereoscopic views
- Panoramic radiograph
- Cross-sectional spiral tomography
- Cone beam computerized tomograph (CT).

Parallax in Horizontal Plane

In this technique, the X-ray tubehead is moved in the horizontal plane. The first radiograph is taken in the

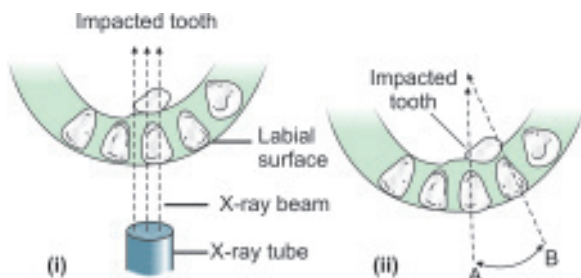


Fig. 22.9: Diagrammatic representation of the parallax technique. The X-ray beam is in the midline (i) and moves posteriorly. (ii) The unerupted tooth moves in the same direction as the X-ray beam, confirming the palatal location of the unerupted tooth

standard fashion with the X-ray beam perpendicular to the film. The second radiograph is taken with the film in the same position but the tube is moved toward the side of the impacted tooth. By the Clark's rule an impacted canine lying on the palatal side of the arch will move in the same direction as the X-ray beam, whereas canine on the labial side will move in the opposite direction. If the canine is lying in the line of the arch, it will not change location in the two radiographs (Fig. 22.9).

Parallax in Vertical Plane

In this technique the X-ray tubehead is moved in the vertical plane.

The method is as follows:

- A dental panoramic radiograph is taken with the X-ray beam positioned upward at 8° to the horizontal.
- An upper standard occlusal radiograph is taken with the X-ray beam positioned downward at 65° – 70° to the horizontal (Fig. 22.10).

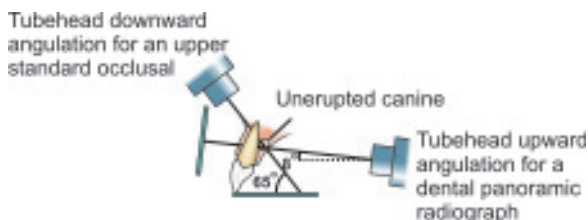


Fig. 22.10: Diagram showing the two different tubehead positions when taking a dental panoramic radiograph and an upper standard occlusal, allowing parallax in the vertical plane

Use

In orthodontics to assess the position of unerupted canines.

Panoramic Radiograph

The panoramic radiograph provides visualization of the entire tooth root and its relationship to the adjacent structures, including the maxillary sinus, nasal floor, and adjacent teeth. The absence of teeth can also be noted.

Use of Cross-sectional Spiral Tomography and Cone Beam CT

This is the most advanced imaging study to visualize the abnormal positioning of the unerupted canine in different planes. By this method there is no need to use the parallax technique.

2 mm cross-sectional spiral tomographs are taken to visualize the relation of canine with the adjacent lateral incisor.

Chapter 23

Radiopaque Lesions in the Jaws

A variety of conditions can affect the jaws are radiopaque relative to the surrounding bone. The degree of radiopacity is very variable depending upon the type and amount of the bony element present in the lesion. Most of these lesions can be detected in plain radiographs but this can be facilitated greatly by using advanced imaging studies such as computed tomography (CT), magnetic resonance imaging (MRI).

The differentiation of these radiopaque lesions with the others can lead to a definite diagnosis by step by step procedures:

- (a) Initially note the specific features of the lesion such as site, size, shape, outline, relative radiodensity, effects on adjacent surrounding structures. Then decide and differentiate this lesion with the other variable radiopacity, i.e. from a normal anatomical structures. In mandible, a bony prominence such as external oblique ridge, mylohyoid line or genial tubercle, an area of dense bone (a dense bone island), an overlying bone (hyoid bone), overshadow of bone (atlas vertebra). In the maxilla, an overlying bone or overshadow of bone (zygoma, anterior nasal spine, nasal cartilages or soft palate).
- (b) *An artefact in the radiograph:* This is due to defect in processing such as real or ghost earring shadows (especially in panoramic radiographs), nose ring or fixer solution splashes.

An artefactual can result as a result of scratches on the intensifying screens.

- (c) The radiopacity is pathological and this can be broadly classified as:
 - Abnormalities of teeth (developmental or genetical).
 - Conditions affecting the bone (Paget fibrous dysplasia).
 - Soft tissue calcifications (salivary calculi).
 - Foreign bodies (amalgam tattoo).

- (d) Next is the comparison of radiological features of unknown radiopacity with the typical radiopaque lesions. The unknown radiopacity may be calcification or change in the radiodensity due to age.

CLASSIFICATION OF RADIOPAACITIES IN THE JAWS

Abnormalities of the Teeth

- Unerupted, embedded, impacted, misplaced supernumerary teeth.
- Hypercementosis.
- Root remnants.

BONY LESIONS HAVING RADIOPAACITIES

1. *Developmental:*
 - Exostoses.
 - Mandibular and palatal tori.
2. *Inflammatory:*
 - Low grade chronic infection-sclerosing osteitis.
 - Osteomyelitis—sequestrum, involucrum.
3. *Tumors Odontogenic (late stages):*
 - Calcifying epithelial odontogenic tumor (CEOT)
 - Ameloblastic fibro-odontoma
 - Adenomatoid odontogenic tumor (AOT)
 - Calcifying cystic odontogenic tumor
 - Cementoblastoma
 - Odontomas
 - Compound
 - Complex
 - Nonodontogenic:
 - Benign:
 - Osteoma
 - Chondroma

Malignant:

- Osteosarcoma
- Osteogenic secondary metastases

4. ***Bone-related lesions:***

- *Osseous dysplasia:*
(Fibro cemento-osseous lesions):
(late stages)
 - Periapical osseous dysplasia
 - Focal osseous dysplasia
 - Florid osseous dysplasia
 - Familial gigantic form cementoma

5. ***Other lesions:***

- Ossifying fibroma
- Fibrous dysplasia

Bone diseases:

- Paget's disease
- Osteopetrosis

Soft tissue calcifications:

- Salivary calculi
- Calcified lymph nodes
- Calcified tonsils
- Phleboliths
- Calcified acne scars

Foreign bodies:

- Intrabony
- Within the soft tissues
- On or overlying the skin

RADIOPACITY CAUSED BY ABNORMALITIES OF THE TEETH

Unerrupted, Embedded, Impacted, Misplaced, Supernumerary Teeth

The radiopacities due to unerupted, embedded, impacted, misplaced, supernumerary teeth are identified by their

characteristic shape, location, outline form and radiodensity. Sometimes these appear as a round in shape (as tooth bud) or a complete formed tooth.

Hypercementosis

Hypercementosis is the deposition of excessive amount of cementum around the apical portion of the root. The cause is unknown but may be due to excessive load on the tooth which result in typically caggy and irregular alteration in outline of the radiopacity in the apical portion of the root.

Root Remnants

The remnants of deciduous and permanent root up to various length are common finding in the radiograph. This can be identified by the site, shape, radiodensity and the presence of radiolucent root canal in the middle portion of the radiopacity and radiolucent line of the periodontal ligament shadow make the diagnosis simple.

Bony Lesions Having Radiopacity

Developmental

Exostoses: Exostoses are small outgrowth of the bone on the surface of the alveolar bone. Endo-ostoses is the growth of the bone from the alveolar bone. These appear as ill-defined radiopacity which is superimposed on the alveolar bone in the radiograph.

Tori: Mandibular tori is present on the lingual aspect of the mandible in the premolar/molar region. This may be unilateral or bilateral. Mandibular tori appears as a round radiopacity protruded from the lingual side of the mandible and visible in occlusal radiograph.

Torus palatinus is present in the midline on either side toward the posterior part of the hard palate.

TUMORS

Calcifying Epithelial Odontogenic Tumor (CEOT)

This tumor is also called pindborg tumor and is a locally invasive epithelial odontogenic neoplasm in which the amyloid material may become calcified.

Radiographic Appearance

This tumor is usually present in molar/premolar region of the mandible. Maxilla is very rarely involved. May be unilocular or multilocular, often associated with an unerupted tooth, especially lower third molar. Outline is variable, frequently scalloped.

In early stage it appears radiolucent, later on, numerous scattered radiopacities usually become evident within the lesion around the crown of associated unerupted tooth. This appearance is described as **driven snow**.

The adjacent tooth shows resorption and displacement. Expansion of cortical plate is present (Fig. 23.1).

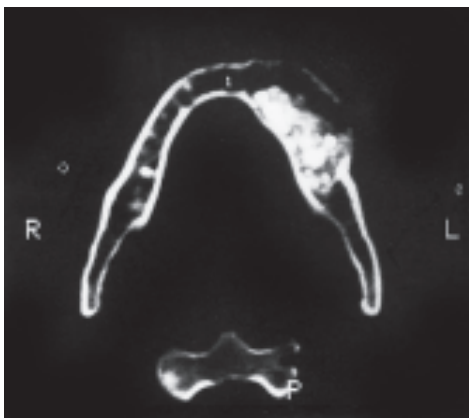


Fig. 23.1: Showing a calcifying epithelial odontogenic tumor will be expansile and will have a mixed radiolucent-radiopaque quality with a variable amount of radiopacity

Ameloblastic Fibro-odontoma

Ameloblastic fibro-odontoma are unilocular or multilocular, often associated with an unerupted tooth and contain enamel or dentine as multiple, small radiopacities or as a solid mass.

Adenomatoid Odontogenic Tumor (AOT)

Adenomatoid odontogenic tumor is usually a cystic hamartoma arising from odontogenic epithelium. This tumor has sometimes been referred to as the '**two thirds tumor**' because about two thirds occur in the maxilla, two thirds occur in young women, two thirds are associated with an unerupted tooth and two thirds of those teeth are canine teeth. It may be discovered by rapid clinical expansion causing pain and sometimes may reach large size (10 cm). Initially the tumors appear without radiographic evidence of calcification and give the shadow of radiolucent lesion suggestive of dentigerous cyst. When calcification starts a mixed radiolucent-radiopaque lesion appears, looking like an ossifying fibroma (Fig. 23.2).

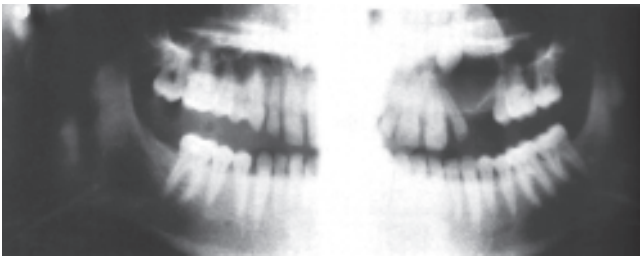


Fig. 23.2: Showing radiographic picture of an adenomatoid odontogenic cyst, a large, well-demarcated radiolucency in the canine-premolar area, and has a canine tooth within it. The impacted tooth is completely within the lesion rather than the lesion arising from the cemento-enamel junction area

Calcifying Cystic Odontogenic Tumor

The calcifying cystic odontogenic tumor is an uncommon tumor with a variable biological behavior. It presents as a hard, painless expansion without causing an alteration in nerve sensation.

An early tumor may be completely radiolucent. As the tumor expands and matures, it will become mixed radiolucent-radiopaque. Radiographic picture ranges from unilocular to a 'soap bubble' appearance, mostly associated with the crown of an impacted tooth; but others may appear in place of a tooth. In some, the radiopacity is so complete that it appears as a bone tumor (Fig. 23.3).

Cementoblastoma

The cementoblastoma is a hamartomatous proliferation of cementoblasts forming disorganized cementum around the apical one half of a tooth root. It usually presents as a hard expansion in the premolar or molar region of either jaw.

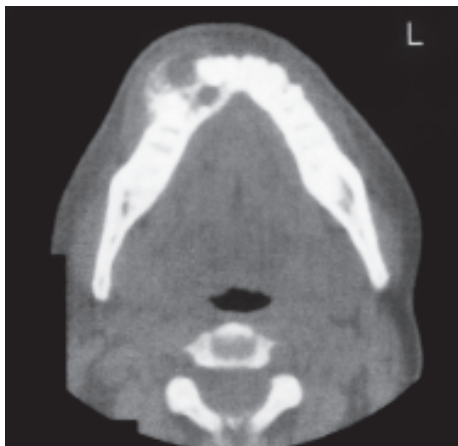


Fig. 23.3: Showing a calcifying odontogenic cyst present as a mixed radiolucent, radiopaque and expansile lesion

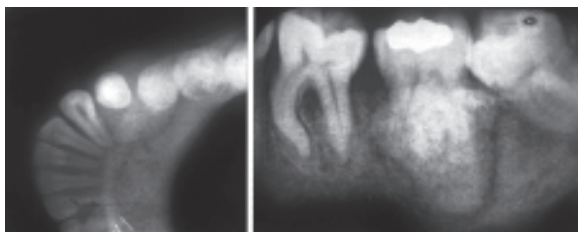


Fig. 23.4: Showing the cementoblastoma occurs in the premolar-molar regions. It arises from the apical one half of the root as a lobulated but symmetric radiopacity with a distinctive radiolucent periphery, mimicking a periodontal membrane space

Radiographically, the lesion characteristically shows a spherical, radiopaque mass around the apical half of the root. There is a characteristic radiolucent margin around the mass giving the impression of a periodontal membrane space. The tooth is vital (Fig. 23.4).

Odontomas

Odontomas are hamartomas of aborted tooth formation. This is of two types—compound odontoma and complex odontoma. Compound odontoma forms multiple small tooth-like structures wherein complex odontoma an amorphous calcified mass is formed. Both types attain a large size (up to 6 cm) and then cease growth. Mostly these are observed during an incidental radiographic examination.

Compound odontomas usually occur more often anterior to the mental foramen, whereas complex odontomas occur most often posterior to the mental foramen.

Radiographically, the compound odontoma presents a gravel-like appearance in which miniature teeth may be noticed. The complex odontoma presents a dense amorphous and irregularly shaped mass. A well-demarcated border with adjacent bone is usually present in both the tumors.

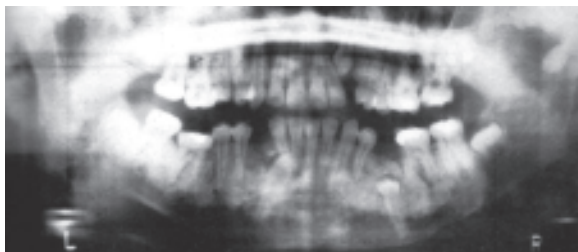


Fig. 23.5: Showing multiple osteomas of the mandible and maxilla in Gardner's syndrome

Osteoma

Osteoma is a slow-growing, painless, discrete bony mass which is palpable if extraosseous. It is usually associated with Gardner's syndrome.

Radiographically, it appears as a well-defined round or oblong radiopacity which emerges from the superficial cortex of the alveolar bone (Fig. 23.5).

Chondroma

Chondroma are benign tumors composed of mature cartilage which arise from cartilage rests within bone or from mesenchymal cells in the periosteum.

Radiographically, chondroma presents as a well-demarcated radiolucent expansion of the bone and are usually painless. Mostly unilocular, but may be multilocular. By calcification of cartilage, foci of radiopacities appears within the tumor.

Osteosarcoma

Osteosarcoma is a malignant neoplasms arising from mesenchymal stem cells and/or their early progeny (loss of the P₅₃ tumor suppressor gene or loss of the retinoblastoma tumor suppressor gene). The average age for osteosarcoma in jaws is 37 years.

Clinically it presents with an expansion of bone, a widened periodontal ligament space (**Garrington sign**), a mobile teeth, a numb lip and pain. More in mandible than maxilla (60% vs 40%).

Radiographical findings are radiopacity which produces the often described “**Sunray**” appearance. This is because of calcified cartilage or distension of reactive periosteum. A widening of the periodontal ligament space, also called Garrington sign (Figs 23.6 and 23.7).



Fig. 23.6: Radiograph showing osteosarcoma with sufficient bone to cause a radiopacity and a so-called sunray appearance



Fig. 23.7: Radiograph of an odontogenic myxoma showing a classic sunray appearance. The sunray appearance and extracortical bone are not of osteosarcoma or necessarily of malignant tumors

In radiographs and computed tomographic (CT) scan show a mottled radiopaque or mixed radiolucent-radiopaque appearance in the medullary space.

Extra cortical bone formation is common and produce the sunray appearance. Cortical bone destruction is also evident.

Osseous Dysplasia

The term osseous dysplasia consists a spectrum of dysmorphic bone and cementum phenomena. These are periapical osseous dysplasia—a localized form of dysplasia found in the anterior mandible; Florid osseous dysplasia a widespread form of dysplasia; Focal osseous dysplasia—a localized form of dysplasia found in single areas other than the anterior mandible.

The pathogenesis of osseous dysplasias involves mesenchymal stem cells that seem to have lost their ability to maintain their structural morphology and therefore produce dysplastic bone.

Periapical osseous dysplasia which is correctly known as periapical cemento-osseous dysplasia is usually asymptomatic that form around the apex of mostly mandibular vital anterior teeth.

The radiographic picture changes from radiolucent to mixed radiolucent radiopaque to completely radiopaque without a change in the tooth vitality (Fig. 23.8).

Florid osseous dysplasia—these lesions are also asymptomatic dysmorphic bone–cementum complexes. Radiographically presents a set of radiolucent radiopaque periapical and interradicular lesions involving the mandible bilaterally and sometimes the maxilla.

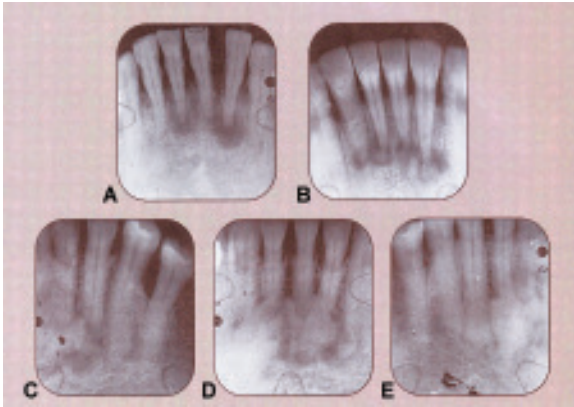


Fig. 23.8: Showing radiographic course of periapical cemento-osseous dysplasia in series of periapical radiographs: (A) beginning radiolucencing; (B) and (C) beginning and more mature radiopacities creating a more dense, irregular, mixed radiolucent-radiopaque appearance; (D) and (E) mature radiopacities creating a pure, well-outlined radiopaque appearance

Ossifying Fibroma

Ossifying fibroma are slow growing, benign neoplasms, most commonly found in jaws related to vast amount of mesenchymal cellular induction into bone (lamina dura). Radiographic appearance in early ossifying fibroma may be radiolucent. As the size increases and matures, they become having mixed radiolucent radiopaque appearance and then completely radiopaque. These tumors are completely asymptomatic and expands slowly. The expansion of these tumors is symmetric from the epicenter of the tumor resulting into a spherical or egg-shaped mass in plain radiographs or CT scan (Figs 23.9A and B).



Fig. 23.9A: Showing radiographic picture of an ossifying fibroma as a spherical, well-demarcated, mixed radiolucent-radiopaque mass

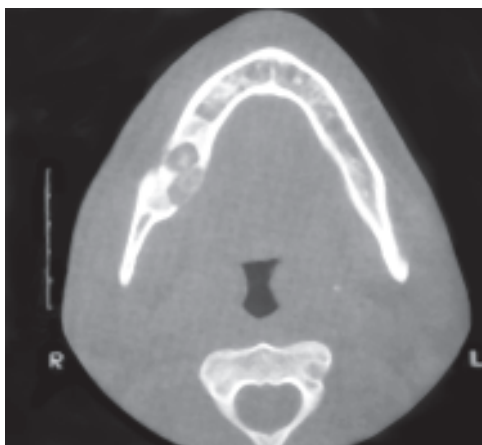


Fig. 23.9B: Showing the spherical to ovoid, well-demarcated, mixed radiolucent-radiopaque mass typical of an ossifying fibroma seen on CT scans

Fibrous Dysplasia

Fibrous dysplasia is a disease of bone maturation and remodeling. The process in fibrous dysplasia is the replacement of normal medullary bone and cortices into a disorganized fibrous woven bone. This bone (fibro-osseous bone) is more elastic and structurally weaker than the original bone. The cause is the deletion of a bone maturation protein during embryogenesis. Usually it is asymptomatic, slowly expanding involving one or more bones. Three types of fibrous dysplasia present—monostotic fibrous dysplasia, involving a single focus in one bone. Polystotic fibrous dysplasia involves two or more bones such as skull, jaws or a facial bone together with ribs, long bones or the pelvis. Two syndromes are associated with polystotic type. McCune-Abright syndrome containing cutaneous melanotic pigmentations called cafe au lait macules and endocrine abnormalities.

Craniofacial fibrous dysplasia involves two or more bones of the jaw-midface-skull complex in continuity. This type is seen relatively often in dental and oral and maxillofacial practices.

Radiographically, all types of fibrous dysplasia show a diffuse, hazy tabecular pattern called “**ground glass appearance**” (Figs 23.10A and B).

But today, mostly radiographic and CT scan pictures of fibrous dysplasia show a homogeneous, tubercular bone pattern replacing the medullary bone and both cortex and often the lamina dura. Its margins are indistinct and show a gradual blend into normal bone. The buccal cortex is more expanded than lingual, but does not displace the inferior alveolar canal.

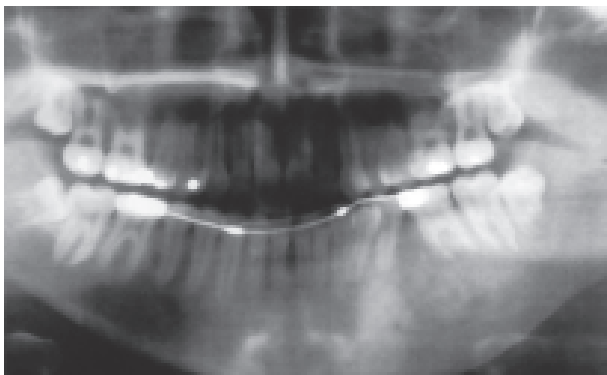


Fig. 23.10A: Showing fibrous dysplasia which produces a nondemarcated, diffuse radiopacity known as a “ground-glass” appearance

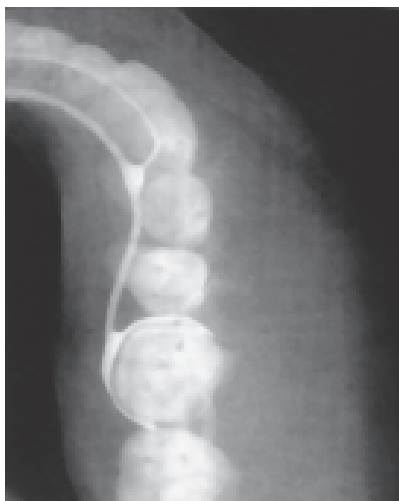


Fig. 23.10B: Showing an occlusal view of fibrous dysplasia which shows its diffuse “ground glass” appearance, expansion, and fibrous dysplasia replacement of the cortical outline

Paget Disease

Paget disease is a condition of excessive bone resorption followed by disorganized bone repair.

Etiology is unknown, but several theories have been advocated of which a slow virus theory is more prevalent. The pathogenesis starts with overactive osteoblastic activity of bone. Then osteoblastic activity responds by osteoblast to lay down haphazard bone in many different directions. The new bone formation result in an increase in vascularity. Later the osteoid becomes mineralized resulting into a dense, sclerotic, end-stage bone that has decreased cellularity and vascularity.

The patient with jaw involvement has expansion of bone with deep bone pain. The affected area feel warm because of increased vascularity. Radiographically, a mottled mixture of radiopacities and radiolucencies present. This radiographic pattern has been termed as '**Cotton wool**' appearance (Fig. 23.11) that has fluffed, radiodense, cloud like aggregation. This type of bone cause root resorption and tooth displacement. Teeth may often exhibit hypercementosis or the loss of the lamina dura.

Osteopetrosis

Osteopetrosis is an inherited disease caused by defective osteoclasts that fail to resorb bone in the normal resorption-remodeling cycle of the skeleton. This results into more dense, less cellular, less vascular bone. The foramen and marrow spaces become compromised and compressed in osteopetrosis. Therefore fracture, thrombocytopenia, anemia, nerve dysfunction (resulting into hearing loss and visual disturbances) may be possible.

Radiographic pictures show astonishing features in skull and jaw. The skull shows extreme density. The mandible shows fractures, unerupted teeth (Fig. 23.12). The maxillary



Fig. 23.11: Showing a mixture of irregular radiopacities, bone expansion and radiolucencies give pagetic bone (cotton wool appearance)

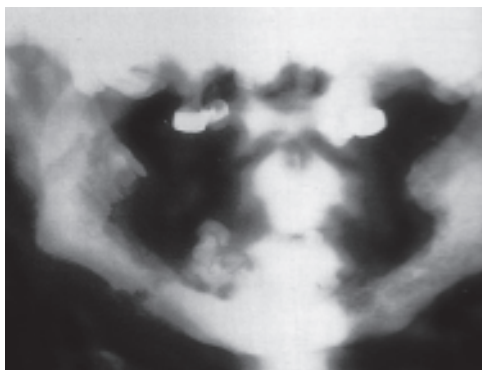


Fig. 23.12: Panoramic radiograph of osteopetrosis showing a pathologic fracture, a retained tooth and a bone sequestrum, all of which are typical of the disease

sinuses may be smaller in size than normal. The cervical spine in early stages show '**Sandwich**' appearance in radiograph. In later stages, generalized opacity appears. Cervical spine may have subluxations and a fracture of the odontoid process.

Chapter 24

Radiolucent Lesions of the Jaws

There are a number of radiolucent lesions in the jaws and the diagnosis depend on thorough history, clinical features and radiological findings in plain radiographs. The process can be greatly facilitated in many cases if advanced imaging studies, such as computed tomography (CT) or magnetic resonance imaging (MRI) are available.

Most of the radiolucent lesions have several similar feature and often individual conditions can present in many different ways.

For a diagnosis by radiography a systematic observation and assessment is important. This starts with the description of the lesion such as site, size, shape, outline, relative radiodensity, effects on adjacent surrounding structures. Then decide whether or not the radiolucency is a normal anatomical structure in the mandible such as mental foramen, or inferior alveolar canal or in the maxilla as maxillary sinus, nasal fossa, nasofrontal fossa. Sometimes the radiolucency may be artefactual. This is as a result of overexposure or superimposed radiolucent air shadows. The radiolucency could be pathological such as congenital, developmental and acquired.

If acquired, the radiolucency could be of the following pathological lesions:

- (a) Infection in periapical tissue:
 - Acute
 - Chronic
- (b) Infection in the jaws:
 - Osteomyelitis
 - Osteoradionecrosis
- (c) Trauma to the jaw
- (d) Cysts
- (e) Tumors or tumor-like lesions
- (f) Bony lesions, such as:
 - Osseous dysplasias
 - Other lesions

The radiolucency could be of the unknown origin and this should be differentiated with the typical radiological features of these possible conditions. Classification of cysts, tumors and other bone-related conditions that present as a cyst-like radiolucency.

Classification of Lesions that Appear Radiolucent (based on the WHO classification)

Cysts	
Odontogenic	Radicular (dental cysts) Residual radicular cyst Lateral periodontal cyst Dentigerous cyst Odontogenic keratocyst (keratocystic odontogenic tumor)
Nonodontogenic	Nasopalatine duct/incisive canal cyst
Tumors and tumor-like lesions	
Benign odontogenic (epithelial with mature, fibrous stroma without odontogenic ectomesenchyme)	Ameloblastoma Squamous odontogenic tumor Calcifying epithelial odontogenic tumor (Pindborg tumor) Adenomatoid odontogenic tumor Keratocystic odontogenic tumor (odontogenic keratocyst)
Benign odontogenic (epithelial with odontogenic ectomesenchyme, with or without hard tissue formation)	Ameloblastic fibroma
Benign odontogenic (Mesenchymal and/or odontogenic ectomesenchyme with or without odontogenic epithelium)	Ameloblastic fibro-odontoma Calcifying cystic odontogenic tumor (calcifying odontogenic cyst) Odontogenic fibroma
Malignant odontogenic	Odontogenic myxoma Odontogenic carcinoma Odontogenic sarcoma

Nonodontogenic intrinsic primary bone tumors	Benign – Fibroma – Chondroma – Central hemangioma – Neurofibroma Malignant – Osteosarcoma – Fibrosarcoma – Chondrosarcoma
Extrinsic primary tumors involving bone	Squamous cell carcinoma
Secondary metastatic bone tumors	
Lymphoreticular tumors of bone	Multiple myeloma Large cell lymphoma Burkitt's lymphoma Ewing's tumor
Langerhan cell disease (Histiocytosis X)	Eosinophilic granuloma Hand-Schüller-Christian's disease Letterer-Siwe disease

Bone-related lesions

Giant cell lesions	Central giant cell lesion (granuloma) Brown tumor in hyperparathyroidism Cherubism Aneurysmal bone cyst
Osseous dysplasia (Fibro cemento-osseous lesion) (early stages)	Periapical osseous dysplasia Focal osseous dysplasia Familial gigantiform cementoma
Other lesions	Osifying fibroma Fibrous dysplasia Simple bone cyst Stafne's bone cavity

INFLAMMATORY LESIONS

Periapical (Radicular) Cyst

Radicular cyst is an inflammatory cyst associated with the root apex of a nonvital tooth. It is the most common cyst of



Fig. 24.1: Radicular cyst

the oral cavity. It develops from the epithelial remnants of Hertwig's root sheath (the cell rests of Malassez). Usually the size is 1.5-3 cm in diameter.

Radiographically, it appears round, unilocular, smooth, well defined, uniformly an apical radiolucency but rarely with the bony expansion unless there is secondary infection. The presence of a thin rim of sclerotic bone around the radiolucency is an indicative of a cyst (Fig. 24.1).

Residual Cyst

The term residual cyst refers to a cyst remaining after the causative tooth has been extracted. Most are small, in the range of 1-3 cm in diameter.

Radiographically, residual cysts appear in a postoperative radiograph as round, unilocular, smooth, well defined, enlarged and darkened uniform radiolucency (Fig. 24.2). Like radicular cysts, even large residual cysts will not show much bony expansion.

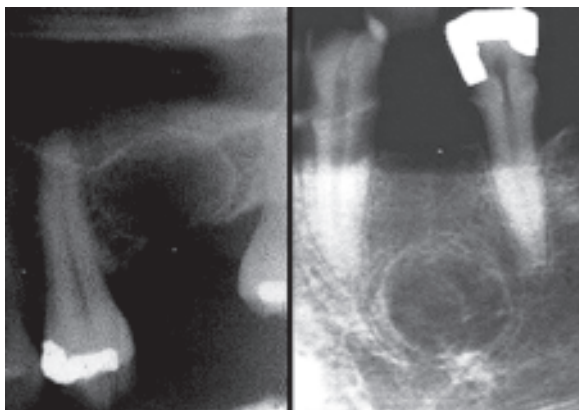


Fig. 24.2: Residual cyst

Lateral Periodontal Cyst

The lateral periodontal cyst is primordial cyst that develops from cell rests of the dental lamina or from remains of the reduced enamel epithelium on the lateral surface of mid-root level in bone.

The lateral periodontal cyst usually presents as an incidental radiographic finding as a round or tear drop-shaped, unilocular, smooth, uniformly radiolucency between teeth. The teeth will be vital and nonmobile and may show root-divergence (Fig. 24.3).

Dentigerous Cyst

This cyst arises from the dental follicle of an unerupted or developing tooth or the remnants of the reduced enamel epithelium after the tooth has formed.

A dentigerous cyst may be discovered as an incidental radiographic finding or by examination in clinical practice.

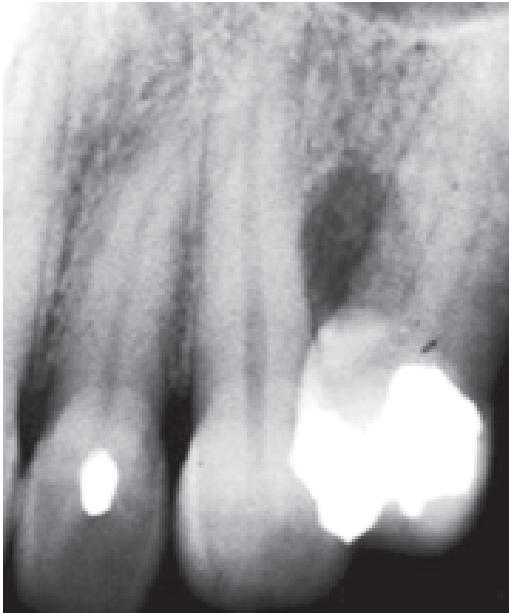
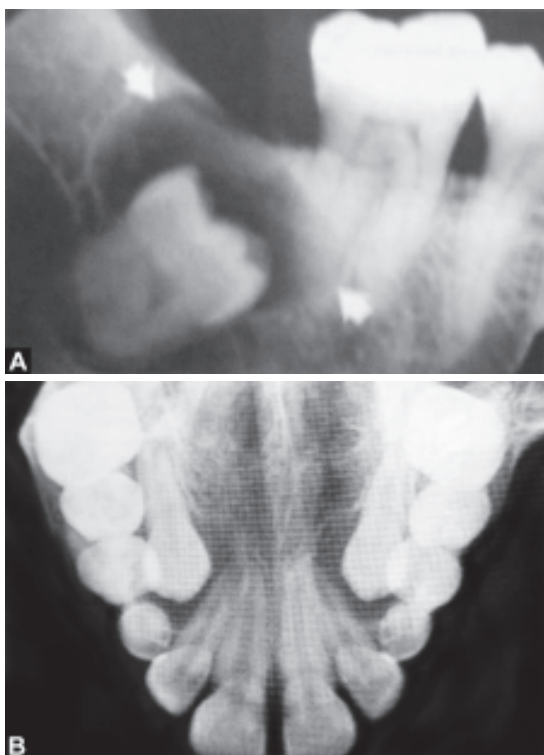


Fig. 24.3: Lateral periodontal cyst

Radiographically, a dentigerous cyst appears as a round or oval, well demarcated, unilocular radiolucency associated with the crown of an unerupted tooth. The tooth may be displaced. The teeth may be displaced to the condylar neck, the nasal floor, high in the maxillary sinus or to the inferior border of the mandible. It may also displace roots of erupted teeth or create a smooth, regular resorption of their roots (Figs 24.4A and B).

Odontogenic Keratocyst

WHO recommended that the odontogenic keratocyst be renamed the keratocystic odontogenic tumor. As they felt,



Figs 24.4A and B: Dentigerous cyst; (A) With impacted mandibular molar tooth; (B) With impacted canines

this resembles to a benign tumor. It is the most unique because of its aggressive nature and recurrence. WHO defines this lesion as a benign uni- or multicystic intraosseous tumor of odontogenic origin with a characteristic lining of parakeratinized stratified squamous epithelium with potentially aggressive, infiltrative behavior. It is believed to develop from the reduced enamel epithelium of the dental follicle (cell rests of serres). Usually the lesion is solitary but in nevoid basal cell carcinoma syndrome (Gorlin's

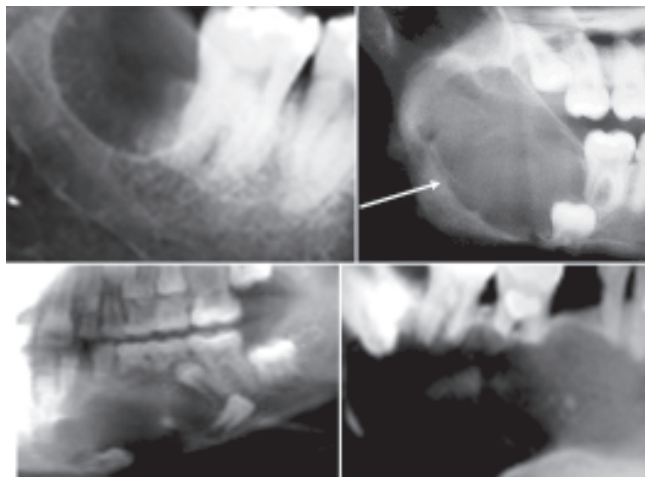


Fig. 24.5: Odontogenic keratocyst

syndrome) multiple odontogenic keratocyst is present. In Gorlin's syndrome along with the multiple odontogenic keratocyst other features present are basal cell carcinoma, skeletal anomalies such as bifid ribs and calcification of the flax cerebri.

Radiographic appearance is oval shaped, pseudolocular or multilocular size variable, uniformly radiolucent smooth and scalloped borders usually present in posterior body/angle of mandible or in anterior region (canine) into maxilla. These cysts extend anteroposteriorly than buccolingually. These cysts also resorb the roots of adjacent teeth in a smooth and regular pattern (Fig. 24.5).

NASOPALATINE DUCT CYST (INCISIVE CANAL CYST)

This cyst develops from epithelial remnants from the two embryonic nasopalatine ducts. Thus these cysts may form anywhere along the ducts course. The usual site is in

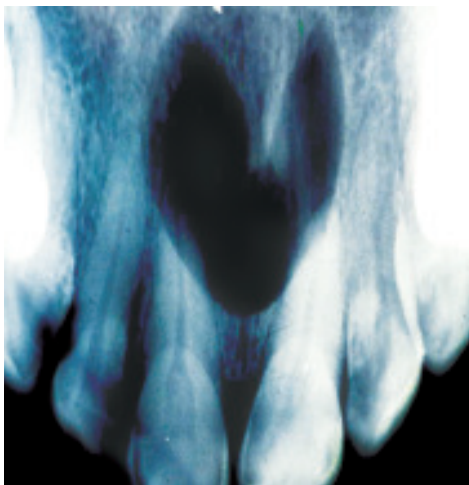


Fig. 24.6: Nasopalatine cyst

midline anterior maxilla just posterior to the upper central incisors.

Radiographically, large lesions appear as a midline, heart shaped, unilocular radiolucency. If large, they create a smooth, regular resorption of the incisor roots. Smaller lesions show a definite, well-demarcated unilocular radiolucency (Fig. 24.6).

PSEUDOCYSTS

Aneurysmal Bone Cyst

Aneurysmal cyst is an expansive osteolytic lesion, spaces filled with blood separated by fibrous septa containing histologically osteolytic type giant cells and reactive bone.

Radiographically, it appears as a multilocular, radiolucency (Fig. 24.7).

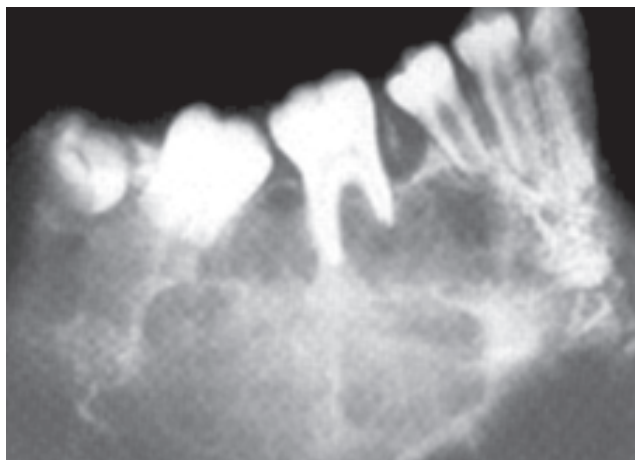


Fig. 24.7: Aneurysmal bone cyst

Solitary (Simple) Bone Cyst

It is an intraosseous pseudocyst lacking an epithelial lining and either empty or filled with serous or sanguinous fluid. The etiology is unknown. Radiographically, it appears as a unilocular, smooth and undulated, moderately well defined, uniformly radiolucent, usually present in anterior region of mandible (Fig. 24.8).

ODONTOGENIC TUMORS

Ameloblastoma

The ameloblastoma is a benign aggressive neoplasm, it exhibits cell replication and growth throughout its existence, but it will not metastasize. It is a specific odontogenic neoplasm that arises from odontogenic epithelium involved with tooth formation. If left untreated it results in progressively destruction of bone. It is usually

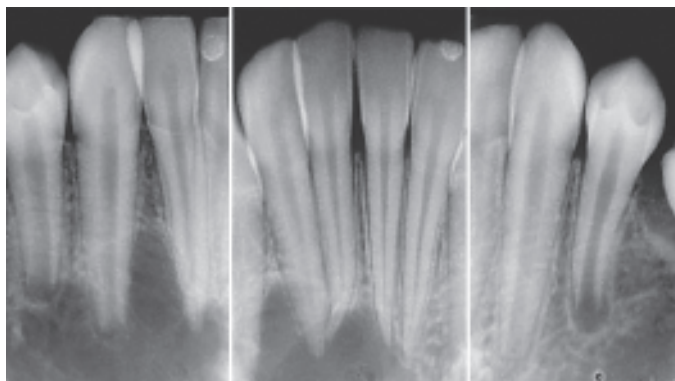


Fig. 24.8: Solitary bone cyst

asymptomatic, peak incidence is between 20 and 35 years of age with no sex preference. The most common site is the third molar area of either jaw. Mandible is more frequently involved than maxilla, ratio is 75% to 25%.

Radiographically, ameloblastoma appears as an expansile radiolucency that may be unilocular and multilocular showing well-demarcated border. Multilocular appearance shows distinct septa dividing the septa into compartments with large discrete areas centrally and with smaller areas on the periphery. The tumor may cause tooth displacement, displacement of the inferior alveolar canal, displacement of the sinus membrane or root resorption. Root resorption is usually smooth regular resorption.

Ameloblastic Fibroma

This is rare benign, mixed type of odontogenic tumor arising from both the odontogenic epithelium and the connective tissue of the developing tooth germ. Histologically, it consists of two types of tissues—odontogenic ectomesenchyme, and epithelial strands and rests.

Radiographic appearance is similar to ameloblastoma, usually multilocular, smooth, well defined radiolucency with internal radiopaque septa. Buccal/lingual expansion of the jaw.

Calcifying Epithelial Odontogenic Tumor (CEOT)

It is an uncommon odontogenic neoplasm with a variable biologic behavior ranging from mild to moderate invasiveness. The peak incidence is in the 40s. It presents as a painless hard expansile tumor without alteration of nerve sensation.

Radiographically, these are radiolucent in the early stages, then numerous scattered radiopacities appear within the lesion, often most prominent around the crown of only unerupted tooth particularly 8/8. This appearance is described as **driven snow** (Fig. 24.9).

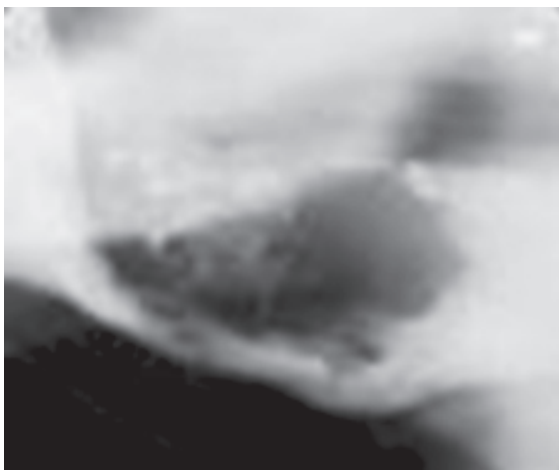


Fig. 24.9: Calcifying odontogenic tumor

Adenomatoid Odontogenic Tumor (AOT)

See Chapter 23.

Calcifying Cystic Odontogenic Tumors

See Chapter 23.

Odontogenic Fibroma

WHO describe it as a rare neoplasm characterized histologically by varying amounts of inactive looking odontogenic epithelium embedded in a mature fibrous stroma. The tumor presents as an asymptomatic expansion of the jaws. Radiologically, it is completely radiolucent just like cyst with a well-demarcated border with dense corticated bone. It may be either unilocular or multilocular. Rarely calcified material may develop internally. The mass will displace the adjacent teeth (Fig. 24.10).

Odontogenic Myxoma

The odontogenic myxoma is a benign intraosseous neoplasm arising from odontogenic mesenchymal origin characterized histologically by stellate and spindle-shaped cells embedded in an abundant myxoid or mucoid intracellular matrix. It presents as an asymptomatic jaw expansion without sensory nerve changes.

Radiologically, it presents as a multilocular radiolucency described as 'honeycombed' but it may also appear as a unilocular radiolucency. Outline is smooth and often scalloped, well defined. Radiolucency presents with fine internal radiopaque septa or trabeculae arranged at right angles to one another resembling the strings of a tennis racket or the letters X and Y.

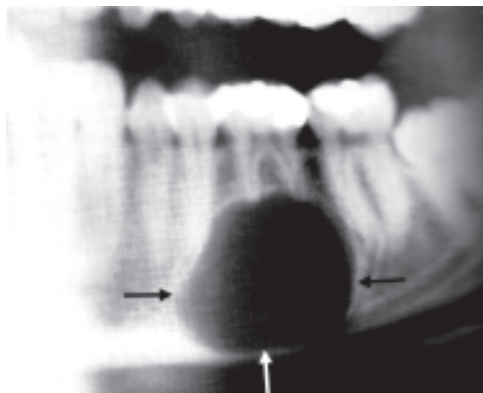


Fig. 24.10: Part of a panoramic radiograph showing a round, unilocular, well-defined radiolucency (arrows) at the apex of 6 which was clinically vital. Histopathology confirmed an odontogenic fibroma

Central Hemangioma

The central hemangioma is a rare, benign tumor that affects the jaw, particularly mandible. It is regarded as hamartoma of the blood vessels in the marrow spaces rather than a true neoplasm. This tumor presents at any age, but mostly occurs in adolescents. Radiographic picture is very variable. The radiographic assessment is important because of life-threatening nature of the lesion. These are:

1. Honeycomb appearance is most commonly found. This is multilocular (the size and number of locules vary considerably), expanding lesion associated with displacement and resorption of associated teeth.
2. A hub or the spokes of a wheel like due to coarse and thick arrangement of trabeculae. This is moderately well-defined zone of radiolucency within which the trabecular spaces are enlarged.

3. Cyst-like radiolucency—which is very rare, well defined round.
4. Surgery appearance—large lesions cause cortical expansion.

Osteosarcoma

See Chapter 23.

Fibrosarcoma and Chondrosarcoma

These are malignant tumors of bone, radiographic picture is irregular, poorly defined radiolucent areas indicating destruction of bone.

Squamous Cell Carcinoma

Squamous cell carcinoma of oral mucosa are usually asymptomatic and produce an indurated exophytic growth. In latter stages, invade the underlying bone to produce a destructive radiolucency. Radiographic picture is irregular area of bone destruction. Moth eaten poorly defined radiolucency appears. Adjacent teeth may be displaced, loosened and/or resorbed or floating in space. Sometimes pathological fracture may result due to destruction of bone.

Metastatic Bone Tumors

The bones of the mandible in particular and to a lesser extent the maxilla are the sites for metastatic deposits from carcinomas of the female breasts, lungs, prostate, kidney and thyroids. The main mechanism for this metastatic spread is a back flow through the venous system. This produces a typical destructive and radiolucency like a malignant lesion.

Radiographic presentation is an irregular radiolucency in the body of the mandible. 'Floating tooth' appearance due to severe bone resorption is apparent. CT scans show a soft tissue mass expanding bone, causing cortical destruction.

Multiple Myeloma

Multiple myeloma is one of the most frequently occurring hematopoietic malignancies present in bone. It is the multifocal proliferation of the plasma cell series within the bone marrow, resulting in over-production of immunoglobulins the clinical presentation is a triad of clinical signs (1) multifocal osteophytic lesions, (2) proliferation of atypical plasma cells in these lesions is a serum monoclonal gammopathy.

Radiographic findings are the earliest and most pronounced classic 'punched out' radiolucencies in the skull, ribs, vertebrae and pelvis. Secondarily, these 'punched out' round, well defined radiolucencies are noted in the jaws.

Langerhans' Cells Disease

Langerhans' cell disease are tumor-like lesions in the bone, caused by proliferation of langerhan cells and eosinophilic leucocytes. Clinically this is of three types:

1. Solitary eosinophilic granuloma—presents in adolescents and young adults, localized to the skeleton.
2. Multifocal eosinophilic granuloma (Hand-Schüller-Christian disease)—begins in childhood till adulthood to 28-30 years. It is chronic and wide spread.
3. Letterer-Siwe disease—occurs in children under 3 years of age, acute or subacute and widespread.

Radiographic picture in all these three types are involving the posterior alveolar process in mandible or

maxilla, small (1-2 cm in diameter), unilocular, smooth, round, relatively well defined radiolucency. Adjacent teeth are not resorbed but the floating teeth are apparent due to loss of periodontal bone.

Central Giant Cell Tumor (Granuloma)

Central giant cell tumors of the jaws are benign but aggressively destructive osteolytic lesion consisting histologically fibrous tissue with hemorrhage and hemosiderin deposits, presence of osteoclast like giant cells and reactive bone formation producing a multilocular expansile radiolucent lesion.

The peak range of occurrence is between 5 and 15 years of age, although some cases are reported in the 20 and 30 years of age. The mandible is three times as frequently involved as the maxilla and presents as a painless, expandible lesion.

Radiographic finding of the central giant cell granuloma presents as a multilocular or some times honeycomb radiolucent lesion that severely thins the buccal and lingual bone including the inferior border which is scalloped. There is displacement of teeth and resorption of interradicular bone. It may also resorb the tooth roots.

Primary and Secondary Hyperparathyroidism

Primary hyperparathyroidism tumors are also known as 'Brown tumors' because they appear as a friable, red brown mass. Radiographic picture in primary hyperparathyroidism is virtually identical to that of the central giant cell tumor. The radiographs in secondary hyperparathyroidism show involvement of all bones with a patchy and mottled



Fig. 24.11: Showing secondary hyperparathyroidism frequently produces tooth mobility, loss of the lamina dura, and a diffuse radiopacity similar to the radiographic appearance of fibrous dysplasia

radiolucent radiopaque appearance. Loss of lamina dura and tooth mobility are commonly seen. Expansion of bone is also seen (Fig. 24.11).

Cherubism

See Chapter 21.

Aneurysmal Bone Cyst

Aneurysmal bone cyst is an expansile, osteolytic lesion multilocular histologically large, blood filled spaces that lack an endothelial lining separated by fibrous septa containing osteoclast-like giant cell and reactive bone, commonly found in adolescents and young adults below 30 years of age. Most commonly found in body or posterior part of the mandible. Radiographically, it appears as a multilocular or soap-bubble like appearance, smooth radiolucency with evidence of faint, internal trabeculations. Adjacent teeth are displaced but rarely resorbed. Buccal and

lingual cortical plates show expansion and described as ballooning or blow out.

Osseous Dysplasia

See Chapter 23.

Fibrous Dysplasia

See Chapter 21.

Ossifying Fibrous Dysplasia

See Chapter 23.

Stafne's Bone Cavity

Stafne's bone cavity is a depression in the body of the mandible in the first molar area. On the lingual aspect near

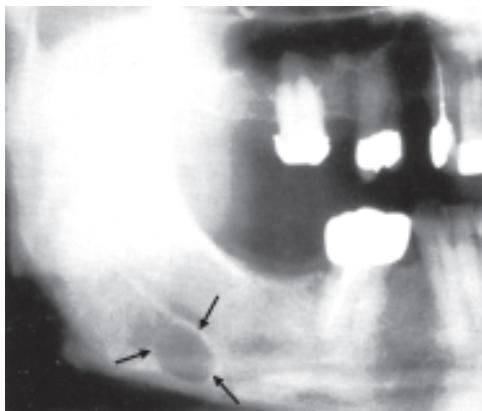


Fig. 24.12: Right side of panoramic radiograph showing the typical cyst-like appearance of Stafne's bone cavity at the angle of the mandible, below the inferior dental canal (arrows)

the lower border containing the aberrant salivary gland tissue.

Radiographically it appears as 1-2 cm in diameter in size, round, unilocular, well defined, uniformly radiolucent area below the inferior alveolar canal at the angle of the mandible. No expansion of bone is seen and no involvement of adjacent teeth (Fig. 24.12).

Chapter 25

Developmental Anomalies of Teeth and Facial Skeleton

DEVELOPMENTAL ANOMALIES

There are a number of developmental anomalies that affect the teeth and facial skeleton. The recognition of these conditions of tooth and bone is important for diagnostic purpose which can be detected radiographically. Developmental anomalies can be classified into:

- A. Anomalies of the teeth
- B. Anomalies of the bone (facial skeleton)

ANOMALIES OF THE TEETH

These abnormalities can be in:

- a. Number
- b. Shape
- c. Size
- d. Structure
- e. Position

Abnormalities in Number of Teeth

Missing Teeth

- Anodontia, Hypodontia or oligodontia.
 - Anodontia is the complete absence of teeth. Hypodontia is the failure of teeth to develop. Oligodontia is the missing of many teeth (Fig. 25.1).
 - The diagnosis of hypodontia can be done by radiographic examination of the underlying bone.
- Hyperdontia
 - Supernumerary
 - Supplemental

Supernumerary teeth can be easily detectable in radiographs. If the supernumerary teeth occurs in between the two maxillary central incisors, it is called a mesiodens (Fig. 25.2), and if it is present distal to



Fig. 25.1: Showing partial anodontia. Note absence of permanent lateral incisor and canine

the third molar, it is referred to as a distomolar. If it is on buccal side of maxillary molar teeth results into displacement of teeth of normal dentition or preventive eruption of the normal teeth. It is called paramolar.

- Syndromes causing hypodontia such as cleidocranial dysplasia, Gardener's syndrome, fibrous dysplasia (Fig. 25.3).

Abnormalities in Shape

- *Fusion*: Fusion is a condition in which two teeth joined together by fusion of two adjacent tooth germs. This result into a single large crown with two root canals which can be visualized only in radiographs (Fig. 25.4).



Fig. 25.2: Showing mesiodens. Supernumerary tooth between the central incisors

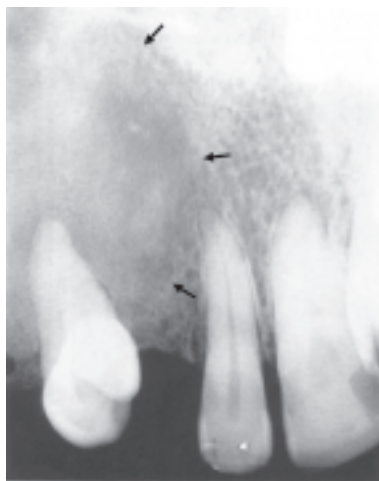


Fig. 25.3: Periapical of the upper right maxilla showing the generalized radio-lucency with the fine internal trabeculation of monostotic fibrous dysplasia, giving a ground glass appearance. The almost imperceptible junction between abnormal and normal bone is arrowed



Fig. 25.4: Showing fusion. Note single crown with two root canals

- *Germination*: Germination occurs when a single tooth germ splits into two teeth due to trauma during its development. It usually appears in the radiograph as two crowns with a single root canal (Fig. 25.5).
- *Concrescence*: Concrescence is the joining of two or more teeth by cementum. In radiograph it is difficult to differentiate concrescence from teeth in close contact.
- *Dens-in-dente (dens. Invaginatus)*: Dens in dente is not a “tooth within a tooth” as generally referred to but an invagination of the enamel organ within the body of the tooth, usually in the cingulum or pit region of the maxillary lateral incisors (Fig. 25.6).



Fig. 25.5: Showing gemination. Note two crowns with common root canal



Fig. 25.6: Showing dens invaginatus

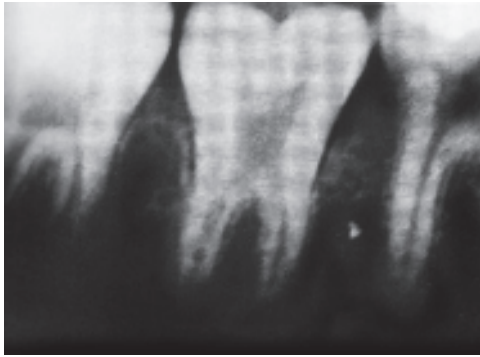


Fig. 25.7: Showing taurodontia. Note the longitudinal distortion and short roots

Abnormalities in Size

- Microdontia—small size of teeth.
- Macrodontia—large size of teeth.
- Taurodontia (bull like)

In taurodontia the body of the tooth is elongated and the crown is enlarged with the extension of the pulp chamber which can be visualized in the radiographs, but the roots are short (Fig. 25.7).

Abnormalities in Structure

This can be divided into:

- Genetic defects
- Acquired defects

Genetic defects are:

- Amelogenesis imperfecta
 - Hypoplastic type
 - Hypocalcified type
 - Hypomature type
- Dentinogenesis imperfecta

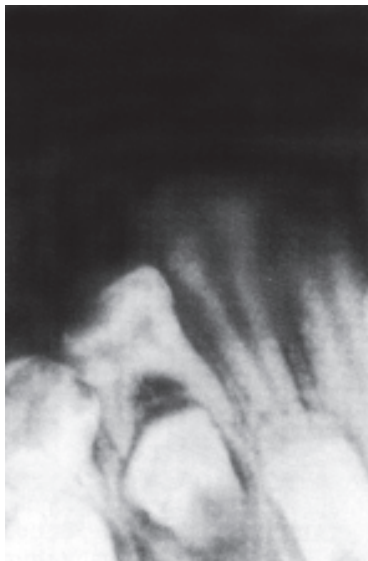


Fig. 25.8: Showing amelogenesis imperfecta

- Shell teeth
- Ghost teeth (Regional odontodysplasia)
- Dentinal dysplasia (rootless teeth)

Amelogenesis imperfecta is a hereditary condition which affects both the deciduous and permanent dentition, the enamel on the teeth is thin and of poor quality and may fracture away completely. The absence of enamel or thin enamel is apparent in radiograph (Fig. 25.8).

Dentinogenesis imperfecta is also a hereditary disturbance. It is characterized by poor enamel that chip off easily. Early calcification of the pulp chambers and canals and short roots are present in permanent teeth (Fig. 25.9).

- Fluorosis
- Discoloration, e.g. Tetracycline staining
- Congenital syphilis



Fig. 25.9: Showing dentinogenesis imperfecta

- Hutchinson's incisors—small, screw-driver shaped, often notched crowns.
- Mulberry molars—moon or dome-shaped molars.
- Turner teeth —this is the defect in enamel caused by infection from overlying deciduous predecessor.
- Measels—causing linear enamel defects.

Abnormalities in Position

- Delayed eruption
- Impacted or embedded teeth
- Malposition of teeth
- Transposition of teeth
- Wandering teeth
- Submerged teeth

Delayed eruption: Mixed dentition is evident in panoramic radiographs in a patient up to 12 years of age. The permanent tooth buds are seen apically to the deciduous teeth to which they replace. The resorption of roots of deciduous teeth can be seen in the radiograph. It is important to differentiate between root resorption and root formation and periapical pathology in the radiograph. If the root formation is not complete, a radiolucent area may appear around the root tip. This radiolucency is the dental root sack.

Some of the systemic diseases such as hypopituitarism and hypothyroidism will cause retarded development and result in delayed eruption of teeth. Other diseases such as cleidocranial dysostosis can result in overextension of the deciduous teeth and retarded eruption of permanent teeth.

Impacted or embedded teeth: The position of impacted teeth can be assessed by the following radiographs or mesiodistal position:

- Periapical
- Panoramic
- Lateral oblique

For buccolingual position:

- Occlusal

The most common teeth which are impacted are mandibular and maxillary molars. In radiographs the bone surrounding and covering the crown portion of tooth can be assessed in radiographs. Periapical radiographs are the most suitable for assessment of the position of impacted tooth and the surrounding bone (Fig. 25.10).

Malposition of teeth: The malposed teeth are those teeth which do not occupy their normal position in the mouth. The transposed tooth is that tooth which occupies the normal position of another tooth.



Fig. 25.10: Tooth impaction of lower third molar

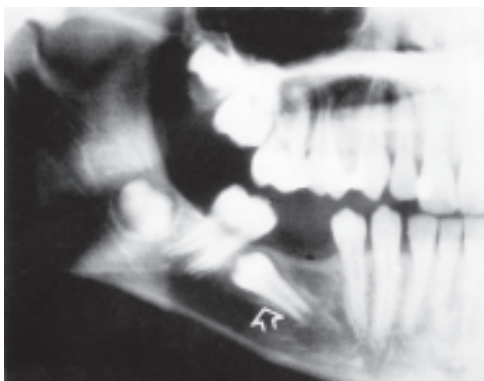


Fig. 25.11: Panoramic radiograph showing distal drift of a wandering 5 (arrowed)

The causes of malposition of tooth are tumors, supernumerary teeth or lack of space.

Wandering teeth: The movement of unerupted teeth by distal tilting of teeth (Fig. 25.11).

Submerged teeth: These teeth do not submerge but rather below the occlusion (infraocclusal) due to ankylosis between

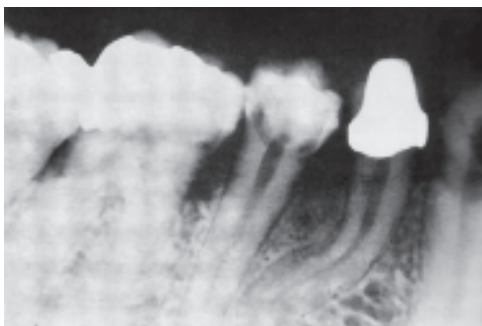


Fig. 25.12: Showing dilaceration.
Note the curved root on first premolar

cementum and bone. It is usually apparent in second deciduous molars.

Anomalies Affecting Roots

- **Number:** Additional roots or supernumerary roots: These additional roots may or may not be detected radiographically. The examples are two rooted incisors, three rooted premolars or four rooted molars.
- **Shape:**
 - **Dilaceration:** Sharp bend at the root apex (Fig. 25.12). This abnormality would present difficulty in the root canal therapy or extraction. It is thought to occur because of trauma during development.
 - Excessive curvature of roots.
 - Bifid roots.
 - Short stumpy roots as in taurodontism.
 - Enamel pearls (enameloma) are small spherical-shaped pieces of enamel usually present in the bifurcation or trifurcation roots of teeth. They are usually discovered in routine radiographic examination and are asymptomatic (Fig. 25.13).

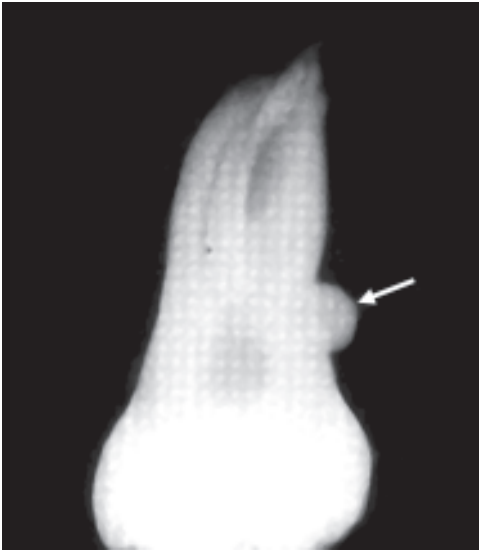


Fig. 25.13: A spherical enameloma is seen on the distal aspect (arrow) of upper second molar

- *Hypercementosis*: Hypercementosis is a condition characterized by the excessive deposition of cementum on the root of the tooth. This excessive deposition of cementum results into club shaped root which causes difficulty during extraction of teeth. Thus the radiograph is essential in this type of condition.

ANOMALIES OF BONE

These are categorized in two:

- a. Abnormalities of the jaws, mandible and/or maxilla.
- b. Abnormalities associated with developmental diseases and syndromes.

Abnormalities of the Jaws

Abnormalities in the mandible, and/or maxilla.

- i. **Micrognathia:** True micrognathia: Caused by bilateral hypoplasia of the jaw (mandible or maxilla) or agenesis of the condyles (Fig. 25.14).

Acquired micrognathia: Caused by ankylosis of the temporomandibular joint early age, unilateral or bilateral.

- ii. **Macrognathia:**

- Genetic
- Relative prognathism (Fig. 25.15)
- Acquired – acromegaly



Fig. 25.14: True cephalometric lateral skull showing micrognathia (underdeveloped mandible) in skeletal Class II



Fig. 25.15: True cephalometric lateral skull showing macrognathia (overgrowth of the mandible) in skeletal Class III

Abnormalities in the Condyles and Coronoid Processes

- Condylar agenesis
- Condylar hypoplasia
- Bifid condyle
- Coronoid hyperplasia

Cleft Lip and Palate

This abnormalities can be classified as:

- a. Cleft lip:
 - Unilateral
 - Bilateral

Both of these are associated with or without alveolar ridge defect.

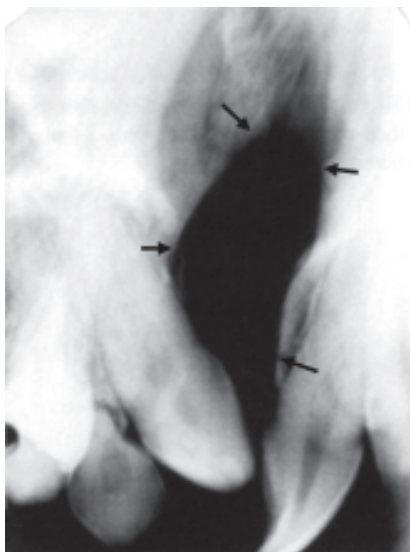


Fig. 25.16: Periapical showing a unilateral cleft palate (arrows). Note lateral incisor is absent

- b. Cleft palate:
 - Bifid uvula
 - Soft palate only
 - Soft and hard palate (Fig. 25.16).
- c. A combination of cleft lip and palate defects:
 - Unilateral (right or left)
 - Cleft palate with bilateral cleft lip

Abnormalities due to developmental diseases and syndromes:

- Cleidocranial dysplasia
- Treacher Collin's syndrome (Mandibular facial dysostosis)
- Gorlin's syndrome (nevroid basal cell carcinoma syndrome)

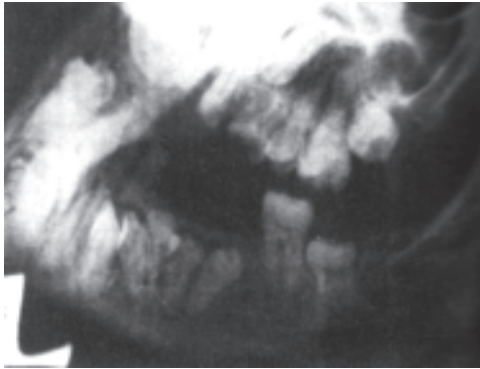


Fig. 25.17: Showing cleidocranial dysplasia. There are many additional teeth but widespread failure of eruption

- Eagle syndrome
- Crouzon syndrome (Craniofacial dysostosis)
- Apert syndrome

Cleidocranial dysplasia causes delayed eruption of permanent dentition. Many permanent teeth may remain embedded in the jaws (Fig. 25.17).

Treacher Collin's Syndrome

Mandibulofacial dysostosis is a rare disease characterized by hypoplasia of facial bones giving all the patient a typical bird face-like appearance. Radiographs show crowding and malposition of teeth partial or complete agenesis of mandible and small paranasal sinuses.

Gorlin's Syndrome

This syndrome is heritable as an autosomal dominant trait. A number of abnormalities may be present in this syndrome. Cysts-like odontogenic keratocysts are common in the body



Fig. 25.18: Showing oblique lateral radiograph of a patient with the basal cell naevus (Gorlin's) syndrome. A very large odontogenic keratocyst involves the whole ramus and body, causing considerable expansion, especially at the lower border

or ramus of the mandible causing considerable expansion especially at the lower border (Fig. 25.18).

Eagle Syndrome

In this syndrome a long calcified stylohyoid ligament is present (Fig. 25.19).

Crouzon's and Apert Syndrome

The radiograph of skull shows the typical copper beaten appearance of the cranium resulting from craniosynostosis

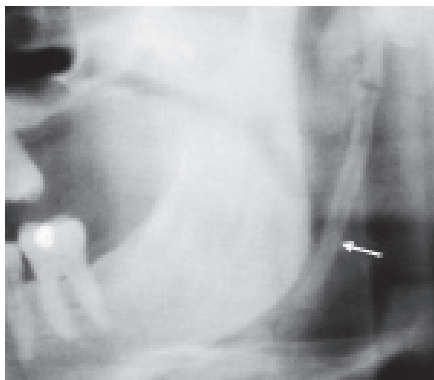


Fig. 25.19: Showing part of a panoramic radiograph showing a long calcified stylohyoid ligament (arrowed), a feature of Eagle's syndrome

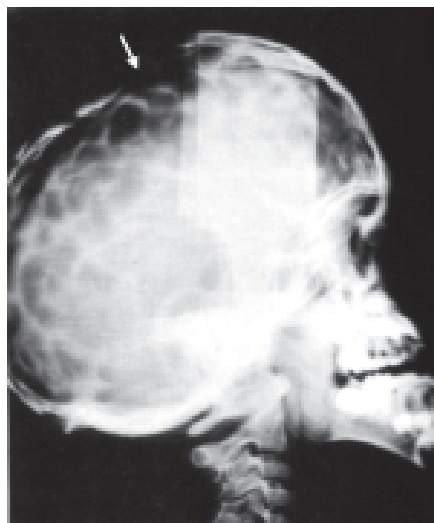


Fig. 25.20: Showing true cephalometric lateral skull showing the typical copper beaten appearance of the cranium resulting from craniosynostosis—premature fusion of the cranial sutures. This appearance is seen in both Crouzon's and Apert's syndromes

(premature fusion of the cranial sutures). There is hypoplastic maxilla and indentation of the anterior fontanelle (Fig. 25.20).

Chapter 26

Dental Caries

INTRODUCTION

Dental caries is the most frequent cause for taking dental radiographs for detection along with the clinical examination. The radiograph is important for identification and recognition of caries.

Development of caries requires three factors—the tooth, the bacteria and the diet containing fermentable carbohydrates. The lactic acid produced by bacteria from the fermentation of carbohydrates that causes the demineralization of the dental hard tissues. The *Streptococcus mutans* plays an important role in the demineralization. This demineralized tooth surface is called a carious lesion or tooth decay, which is often referred to as a cavity. The cavitation or hole in tooth is the result of the caries process or tooth decay (Fig. 26.1).

The caries is detected both by clinical examination and a radiographic examination. The radiographs are required to



Fig. 26.1: When caries is confined to enamel, it exhibits a triangular configuration



Fig. 26.2: Proximal and occlusal demineralization and cavitation nearing the pulp chamber of two vital teeth

evaluate the extent and severity of carious lesions. Radiography is useful because the caries process causes demineralization of enamel and dentin. Thus the carious lesion appears as a radiolucent (dark) zone because the demineralized area of tooth does not absorb as many X-ray photons as the unaffected portion (Fig. 26.2).

Radiography is a valuable supplement to clinical examination of the teeth for detecting caries. The radiographs can reveal carious lesions both in occlusal and proximal surfaces that would otherwise impossible to be detected by clinical examination.

The bitewing radiograph is the most useful for detection of caries. A periapical radiograph is also useful for evaluation of caries and for detecting changes in the periapical bone.

An illuminator with magnifying glass or view box is required for accurate viewing of radiographs and for interpretation of images.

The use of pocket-sized magnifying glass is helpful in evaluating the dental caries and can be used to detect minor changes in density and contrast in radiographic images.

A proper angulation is required to prevent any overlapped contacts. Improper horizontal angulations cause overlapped contact areas and make it impossible to interpret the interproximal caries.

Incorrect exposure can result in too dark or too light films, which are difficult to detect caries.

RADIOGRAPHIC DETECTION OF CARIES

The dental caries can be classified according to the location of the caries on to the tooth surface. These are interproximal, occlusal, buccal, lingual and root surface or cervical caries.

INTERPROXIMAL CARIES

When the caries is found between the two adjacent surfaces of teeth is termed interproximal caries.

The caries in the proximal surfaces are most commonly found in the area, between the contact point and the free gingival margin (Fig. 26.3). Lesions, which are confined to enamel, may not be evident radiographically until approximately 30-40% demineralization has occurred. The actual depth of penetration of a carious lesion is often deeper than seen radiographically.

The shape of early radiolucent lesion in the enamel assumes a triangular configuration; the apex of the triangle is seen at the dentinoenamel junction (DEJ), with the base at the tooth surface, spreading along the enamel rods. When the caries reaches the DEJ, it spreads along the junction, forming the base of a second triangle with apex directed towards the pulp chamber.

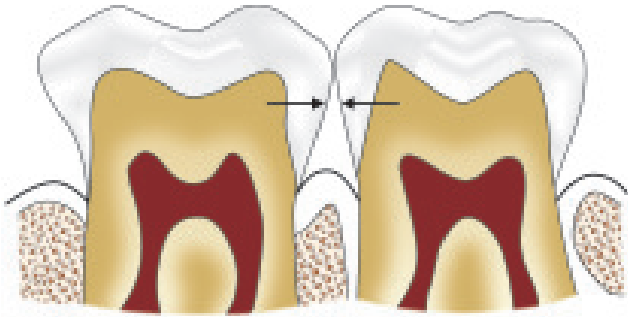


Fig. 26.3: The most common site of development of caries is at or just below the contact area

Interproximal caries can be classified as incipient, moderate, advanced and severe.

Incipient Interproximal Caries

Incipient means beginning to exist or appear. This is present only in enamel and it is difficult to be detected by radiography.

This caries extends less than half way through the thickness of enamel.

A lesion extending into the dentin in the radiograph may be easier to be detected.

Moderate Interproximal Caries

It is seen only in enamel. Caries extends in this more than half way through the thickness of enamel but does not involve the DEJ.

Advanced Interproximal Caries

The lesion affects both enamel and dentin. Caries extends to or through the DEJ and into dentin but does not extend more than half the distance toward the pulp. The lesion, which

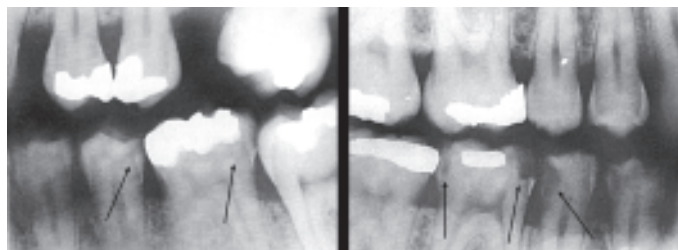


Fig. 26.4: Advanced interproximal caries

extends into the dentin more than half way to the pulp are always cavitated otherwise the surface cavitation is very small in lesions present in the enamel (Fig. 26.4).

Severe Interproximal Caries

This lesion involves both enamel and dentin and appears as cavitations on the tooth surface clinically. The caries extends through the enamel and dentin more than half the distance toward the pulp.

OCCLUSAL SURFACE CARIES

Occlusal means the chewing surfaces of teeth. Carious lesions in children and adolescents are more commonly occurs on the occlusal surfaces of posterior teeth.

Occlusal caries usually starts in the sides of a fissure wall and then tends to penetrate nearly perpendicular toward the DEJ. The occlusal caries is difficult to see on a radiograph because of the superimposition of the dense buccal and lingual enamel cusps. Occlusal caries is not seen on a radiograph until there is involvement of the DEJ.

This can be classified into incipient, moderate and severe.

Incipient Occlusal Caries

This caries must be detected clinically with a probe because the incipient caries cannot be visible on a radiograph.

This is because when an occlusal caries is confined to enamel; the surrounding enamel often obscures the lesions. As the carious process progresses deep, a radiolucent line extends along the DEJ.

Moderate Occlusal Caries

A vary thin radiolucent line appears on radiographs because in this, the caries extends into the dentin under the enamel of the occlusal surface of the tooth.

Severe Occlusal Caries

The classic radiographic appearance in severe occlusal caries extending into the dentin is a broad based radiolucent zone often, beneath the fissure with little or no apparent changes in the enamel. The deeper the occlusal lesion the easier it is to detect on the radiograph.

Severe occlusal caries is apparent clinically and appears as a cavitation in a tooth (Fig. 26.5).

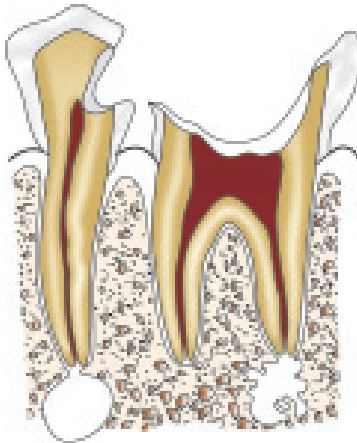


Fig. 26.5: Two nonvital pulps and periapical inflammation results due to severe demineralization and cavitation reaching the pulp chamber and canal

BUCCAL AND LINGUAL SURFACE CARIES

It is difficult to differentiate between buccal and lingual caries on a radiograph because of the superimposition of the densities of normal tooth structure. Buccal and lingual caries often occur in enamel pits and fissure of teeth. When small, these caries are usually round, as they enlarge they become elliptic or semilunar. On radiograph, these caries appear as sharp, well-defined borders.

ROOT SURFACE CARIES (CERVICAL CARIES)

Root surface caries involve both cementum and dentine located just below the cervical region of the tooth and are usually associated with gingival recession.

The most common locations are the exposed roots of the mandibular premolar and molar areas. The root surface caries appears on a radiograph as a cupped out or crater-shaped radiolucency just below the cemento-enamel junction (CEJ).

A pitfall in the detection of root caries is that a surface may appear to be caried as a result of the cervical burnout phenomenon (Fig. 26.6).

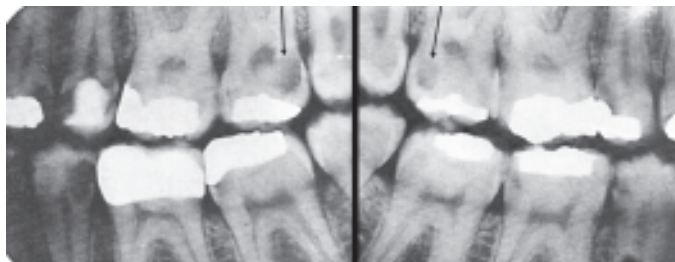


Fig. 26.6: Cervical burnout in posterior teeth

RECURRENT OR SECONDARY CARIES

Caries developing at the margin of an existing restoration is termed recurrent caries. This caries develops because of inadequate cavity preparation or defective extension of the restoration leading to plaque accumulation or incomplete removal of caries prior to placement of restoration.

It appears as a radiolucent area just beneath a restoration on a radiograph. Recurrent caries are most frequently detected in radiographs at mesio gingival and disto gingival margins.

Restorative materials vary in their radiographic appearance such as older calcium hydroxide without barium, lead or zinc (which give radiopacity) appear radiolucent and may resemble recurrent caries. Composite, plastic or silicate restorations also may simulate carious lesions.

RAMPANT CARIES

Rampant caries means rapidly progressing carious destruction of teeth and is usually seen in children with poor dietary and oral hygiene habits. Rampant caries may also be seen in people suffering xerostomia.

Rampant caries occurs most commonly in mandibular anterior teeth and appears radiographically as severe caries destruction that affects numerous teeth.

Chapter 27

Periodontal Disease

INTRODUCTION

Disorders of the periodontium is known as periodontal disease. The most common periodontal diseases are gingivitis and periodontitis. Gingivitis involving the gingiva surrounding the teeth is a soft tissue inflammation. The periodontitis involves the soft tissue attachment, i.e. gingiva and periodontal ligament and supporting bone around the involved tooth. Mostly gram-negative bacteria play an important role in the initiation of periodontal disease. The resulting inflammatory process causes loss of and apical migration of the epithelial attachment, resulting in pocket formation.

Gingivitis clinically appears as gingival swelling, edema and erythema. Periodontitis has clinical manifestation as bleeding, purulent discharge, edema, resorption of the alveolar crest and tooth mobility. In periodontal diseases there are active periods of inflammation and tissue destruction followed by healing and quiescent periods.

Radiographs play an important role in the assessment of periodontal disease by obtaining vital information about supporting bone that cannot be obtained clinically. The appearance of alveolar bone affected by periodontal disease differs from that of healthy alveolar bone in radiograph.

In periodontitis, the alveolar crest is no longer located 1.5-2.0 mm apical to the cemento-enamel junction and cannot appear radiopaque. Periodontal disease may result in severe destruction of bone and alveolar crest appear indistinct.

Bone loss is estimated as the difference between the physiologic level of bone and the height of the remaining bone (Fig. 27.1).

Both clinical and radiographic examinations are necessary to detect periodontal disease. Clinical examination gives information about the soft tissue and radiographs permit evaluation of bone. Radiographs help in identifying the extent

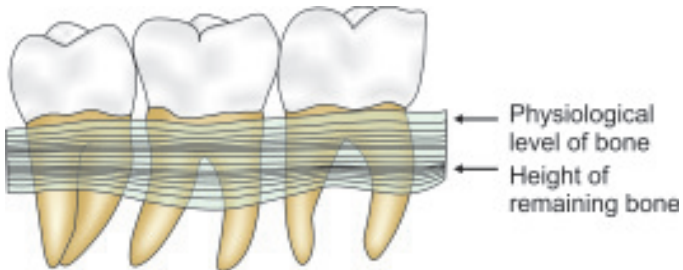


Fig. 27.1: Showing estimation of bone loss

of destruction of alveolar bone and features of the periodontium, which influence the prognosis.

Clinical examination should include periodontal probing, a gingival index, mobility charting, and an evaluation of the amount of attached gingiva.

Radiographs are the adjunct to the diagnostic process. It demonstrated any advanced periodontal lesions. A complete diagnosis of periodontal disease requires a clinical examination along with radiographic assessment. Radiograph gives an overview of the amount of bone, its pattern, distribution and loss of bone that has occurred due to periodontal disease (Fig. 27.2).

The periapical film is the choice for evaluation of periodontal disease.

Periapical radiograph with the parallel technique is the best for the demonstration of height of crestal bone in relation to the tooth root.

Interproximal (bitewing) images give more accurately the distance between the cementoenamel junction (CEJ) and the crest of the interradicular alveolar bone.

The vertical bitewing radiograph can be used to examine bone levels in the mouth and can be used as a post-treatment or follow-up film.

The panoramic radiographs are not recommended for evaluation for periodontal disease because panoramic views

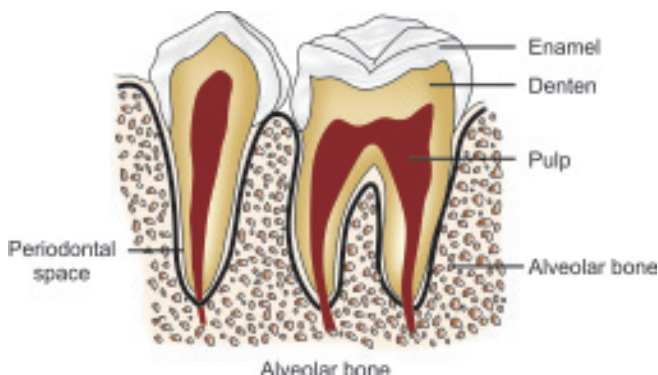


Fig. 27.2: Diagram showing structures of tooth in periapical film

underestimate minor marginal bone destruction and overestimate major destruction.

RADIOGRAPHIC FEATURES IN PERIODONTAL DISEASE

The changes seen radiographically in periodontal disease are same as changes seen with inflammatory lesions of bone. These are:

- Changes in the morphology of the supporting alveolar bone.
- Changes to the internal density and trabecular pattern. Changes in morphology are the loss of the interproximal crestal bone and bone overlapping the buccal or lingual aspect of tooth roots. Changes to the internal aspect of alveolar bone reflect a reduction or an increase in bone structure.

A reduction of bone structure appears as radiolucency because of decrease in number and density of trabecular pattern.

An increase in bone density is seen as increase in radiopacity (sclerosis). Periodontal disease usually involves a combination of bone loss and bone formation. Acute periodontitis gives a picture of bone loss whereas chronic periodontitis gives a greater component of bone sclerosis.

Periodontitis can be divided into:

- Mild periodontitis
- Moderate periodontitis
- Severe periodontitis
- Aggressive Periodontitis
- Periodontal abscess

MILD PERIODONTITIS (FIG. 27.3A)

In early periodontal disease, the normally occurring sharp angle between lamina dura and alveolar crest may lose its normal cortical margin and appear rounded off, having an irregular and diffuse border.

MODERATE PERIODONTITIS (FIG. 27.3B)

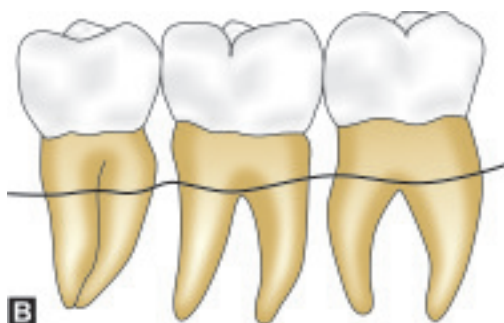
In moderate periodontitis the destruction of alveolar bone extends more result in changes in alveolar crest and defects in the morphology of alveolar crest.

The pattern of bone loss may be horizontal or vertical, and the distribution may be localized or generalized.

SEVERE PERIODONTITIS (FIG. 27.3C)

The bone loss is so extensive in severe periodontitis that the teeth show excessive mobility and drifting and may be lost because of inadequate support. Horizontal and vertical bone loss are very extensive in severe periodontitis.

Furcation involvement is about three times more in maxillary molars than mandibular molars. The loss of interradicular bone in the furcation of a maxillary molar may



Figs 27.3A to C: Periodontitis (A) Mild, (B) Moderate, (C) Severe

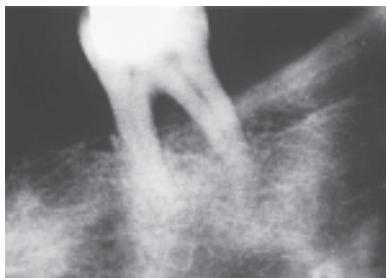


Fig. 27.4: Showing furcation involvement in lower molar tooth

originate from buccal, lingual or distal surface of the tooth. In maxillary permanent first molar the most common route of furcation involvement is from the mesial side of tooth. The furcation involvement is not very prominent in radiographs in maxillary molars because of presence of palatal root while it is more prominent in mandibular molars. Occasionally this pattern of bone destruction may appear as an inverted 'J' shadow in the radiograph (Fig. 27.4).

AGGRESSIVE PERIODONTITIS

Periodontitis with an aggressive and rapid nature occur in patients under 30 years of age. This results in early bone loss and loosening of tooth.

This may be localized and generalized periodontitis such as localized juvenile periodontitis, generalized juvenile periodontitis.

In localized aggressive periodontitis the bone loss is vertical while in generalized aggressive periodontitis there is rapid bone loss in the vertical or horizontal pattern with involvement of several teeth.

PERIODONTAL ABSCESS

It appears as a radiolucent lesion in the root portion of the tooth. Sometimes a bridge of bone may be present over the coronal portion of the abscess separating from the crest of the alveolar ridge.

HORIZONTAL BONE LOSS

Horizontal bone loss is a radiographic appearance of loss of alveolar bone in height. Alveolar crest is horizontal and parallel with the occlusal plane or the cemento-enamel junction of the adjacent (i.e. 1 mm) teeth but is positioned apically more from the line of the cemento-enamel junction. The crest of the buccal and lingual cortical plates and the interdental bone are also resorbed in horizontal bone loss. Horizontal bone loss appears in multiple teeth.

VERTICAL BONE LOSS

The alveolar crest appears as an oblique angulations to the line of cemento-enamel junction of the adjacent teeth in the area of involved teeth. The vertical bone loss are more commonly localized to one or two teeth. The infrabony defect is a vertical deformity within bone and it extends apically along the root from the alveolar crest (Fig. 27.5). Infrabony defect may be of three types:

- a. **Three walled defect:** When tooth is surrounded by three bony walls buccal and lingual cortical plates remain.
- b. **Two walled defect:** When one buccal or lingual wall resorbs.
- c. **One walled defect:** When both buccal and lingual cortical plates have been lost.

BUCCAL OR LINGUAL CORTICAL PLATE LOSS

The buccal or lingual cortical plate adjacent to the teeth may resorb. This is indicated by an increase in the radiolucency of

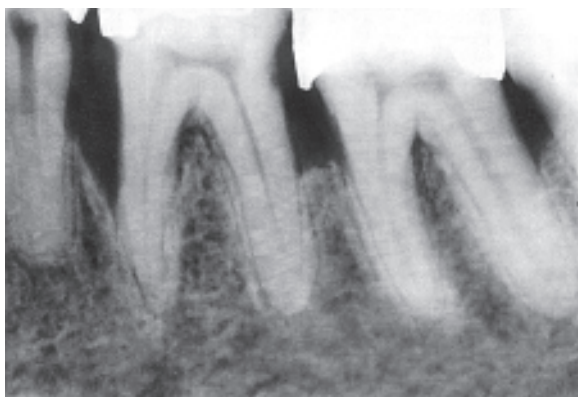


Fig. 27.5: Vertical and horizontal bone loss in the mesial and distal side of the first lower molar

the root of the tooth adjacent to the alveolar crest. In radiograph it appears as semicircular with the apex of the radiolucency directed apically in relation to the involved tooth.

Conditions which shows radiographic changes in periodontium are:

1. **Occlusal trauma:** Traumatic occlusion results into degenerative changes in the tooth supporting structure and gives radiographic findings which include widening of the periodontal ligament space, widening of the lamina dura, an increase in the number and size of trabeculae. The clinical features of traumatic occlusion may be increased mobility, wear facets, unusual response to percussion and later on lead to pocket formation.
2. **Tooth mobility:** Tooth mobility is due to widening of the periodontal space which may result from occlusal trauma or a lack of bone support arising from advanced bone loss. The affected tooth shows radiographic changes

of broadening of lamina due and hazy and also shows increased density (osteosclerosis). In a multirrooted tooth widening of the periodontal space at the apices and in the furcation region.

3. ***Open contacts:*** When the mesial and distal surfaces of the adjacent teeth do not touch this may result into entrapment of food debris which may damage the soft tissue and induce an inflammatory response and result into the development of localized periodontal disease. Abnormal tooth alignment may cause difficulty in maintaining oral hygiene that area which may result into periodontal disease.
4. ***Local irritating factors:*** Calculus deposits can prevent effective cleansing of a sulcus and lead to the progression of periodontal disease and enhance plaque formation (Fig. 27.6). Overhanging margins of defective restorations or poorly contoured margins of restoration can lead of accumulation of plaque or cause irritation to the soft tissue, which may result into the development of periodontal disease (Fig. 27.7).

SYSTEMIC DISEASES CAUSING PERIODONTAL DISEASE

Diabetes

Patients with uncontrolled diabetes are more disposed to develop periodontal disease than are those with normal glucose metabolism. These patients also show rapid alveolar bone resorption and are more prone to develop periodontal abscesses.

AIDS

The incidence of and severity of periodontal disease is high in patients with acquired immunodeficiency syndrome. In



Fig. 27.6: Subgingival calculus resulting in bone loss



Fig. 27.7: Overhanging restoration resulting in bone loss

these patients, periodontal disease may lead to bone sequestration and loss of several teeth. These patients may not respond to standard periodontal therapy.



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